A Comparison of Similar Aerosol Measurements made on the NASA P3-B, DC-8 and NSF C-130 Aircraft during TRACE-P and ACE-Asia

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ABSTRACT:

Two major aircraft experiments occurred off the Pacific coast of Asia during spring, 2001: the NASA sponsored Transport and Chemical Evolution over the Pacific (TRACE-P) and the NSF sponsored Aerosol Characterization Experiment-Asia (ACE-Asia). Both experiments studied emissions from the Asian continent (biomass burning, urban/industrial pollution, and dust). TRACE-P focussed on trace gases and aerosol during March/April and was based primarily in Hong Kong and Yokota AFB, Japan and involved two aircraft: the NASA DC-8 and the NASA P3-B. ACE-Asia focussed on aerosol and radiation during April/May and was based in Iwakuni MCAS, Japan and involved the NSF C-130. This paper compares aerosol measurements from these aircraft including aerosol concentrations, size distributions (and integral properties), chemistry, and optical properties. Best overall agreement (generally within 15%) was for physical properties of the sub-μm aerosol, including CN concentrations, scattering coefficients (during the ACE-Asia/TRACE-P comparisons), and DMA and OPC accumulation mode size distributions. Larger differences (typically over 35%) were often observed for parameters related to the super-μm aerosols (total scattering and absorption coefficients, coarse mode FSSP and OPC size distributions/integral properties, and soluble chemical species usually associated with the largest particles—e.g. Na, Cl, Ca, and Mg), where aircraft sampling is more demanding. Some differences reflect different inlets (e.g. LTI enhancement of coarse mode aerosol), differences in sampling lines, and instrument configuration and design. Means and variances of comparable measurements for horizontal legs were calculated for each platform and allow for an assessment of instrument performance. These results will provide a basis for integrating aerosol data from these aircraft platforms for both the TRACE-P and ACE-Asia experiments.

1. Introduction:

The NASA sponsored Global Tropospheric Experiment (GTE) and NSF sponsored Aerosol Characterization Experiment (ACE) are ongoing research programs for studying tropospheric chemistry (GTE) [McNeal, et al., 1998] and aerosol properties (ACE) [Bates, et al., 1998, Huebert, et al., submitted 2002] in the global atmosphere. Field missions from both research programs during the past two decades have sampled remote areas of the atmosphere, including over the Arctic, the Brazilian rain forest, the tropical Atlantic, the tropical Pacific, the southwestern Pacific near Australia, and the western Pacific. A major goal of these campaigns was to understand and characterize the concentration and variability in gas and aerosol species that influence properties of the global atmosphere and to assess the role of anthropogenic sources.

The East Asia region is undergoing rapid population growth and economic/industrial development with fossil fuel combustion and energy use increasing at a brisk rate. Energy use has increased about 5% yr^{-1} during the last decade; this increase is predicted to continue during the next twenty years [U.S. Dept. of Energy, 1997]. Along with this increase in economic activity and population, emissions from urban/industrial sources and biomass burning are expected to rise. These emissions include O_3, methane, CO and CO_2, NO_x, and aerosols (sulfates, nitrates, ammonium, black carbon, organic carbon, etc.). Additionally, Asia is a significant source of dust aerosols to the Pacific atmosphere.

The aerosol component of the Asian outflow can impact the atmosphere in several ways. It can be important in geochemical cycles (dust input/iron fertilization of oceans [Duce and Tindale, 1991] and the sulfur, nitrogen, and carbon budgets [Galloway, et al., 1984]). These aerosols can affect tropospheric chemistry by acting as sources/sinks for various chemically important gases through gas-to-particle conversion, cloud processes, and providing reaction sites for both homogeneous and heterogeneous chemistry (especially the dust component [Dentener, et al., 1996]). Aerosols can also affect the hydrological cycle/precipitation [Twomey, et al., 1984; Rosenfeld, 1999; Ackerman, et al., 2000]. Additionally, aerosols have an impact on global/regional climate through their so-called “direct” and “indirect” radiative effects.

The aerosol direct effect is due to the scattering and absorption of solar and terrestrial radiation by the particles themselves [Penner, et al., 1992; Charlson, et al., 1991]. The direct effect of sulfates in the atmosphere has been well characterized [Charlson, et al., 1991], however the direct effect of absorbing aerosols (BC, organic and other carbonaceous aerosols, and dust) is less well known. Overall, estimates of the direct effect of aerosols on the radiative balance of the earth’s atmosphere result in a negative “cooling” effect with a forcing term of approximately –1 W m^{-2} [Kaufman, et al., 1997]. However, there are uncertainties in this forcing, due mostly to the role of absorbing aerosols. Even larger uncertainties are associated with the aerosol indirect effect that arises from the “activation” of aerosols in clouds to form cloud condensation nuclei (CCN) and their resulting influence on cloud albedo, cloud lifetime and microphysics [Andreae, 1995; Charlson and Heintzenberg, 1995].

The Transport and Chemical Evolution over the Pacific (TRACE-P) experiment focussed on trace gases and aerosols in the Asian outflow during March/April and was based primarily in Hong Kong and Yokota AFB, Japan. Two aircraft were involved: the NASA DC-8 and P3-B. The Aerosol Characterization Experiment-Asia (ACE-Asia)

focussed on aerosols and their radiative effects during April/May and was based in Iwakuni MCAS, Japan and involved the NSF/NCAR C-130. The spring season was chosen to correspond to meteorological conditions that result in the maximum Asian outflow over the Pacific [Merrill, 1989].

The unusual opportunity to combine the extensive data sets from these two major campaigns was long recognized as valuable in addressing some of the issues outlined above over greater spatial and temporal scales. Hence, inter-comparison flights were planned to ensure data sets were consistent and comparable. Five comparison flights (three between the P3-B and DC-8, two between the P3-B and the C-130) were coordinated through interagency cooperation where time was devoted to flying "wingtip-to-wingtip" (within 500 m, typically less). The inter-comparisons included 12 horizontal legs and 13 vertical profiles, allowing for comparison of data sampled in a variety of altitudes and conditions. The results of these inter-comparisons provide a basis for integrating aerosol and gas phase data from the aircraft platforms for both the TRACE-P and ACE-Asia experiments. These links improve the spatial, temporal, and statistical characterization of the Asian aerosol and help identify and constrain uncertainties when comparing different data sets.

2. Instrumentation to be compared:

The payloads of the three platforms discussed in this paper (P3-B, DC-8, and C-130) each had a suite of instruments for measuring a variety of gas phase species, aerosols, and their precursors [Raper, et al., submitted 2002; Huebert et al., submitted 2002]. Separate papers will focus on the TRACE-P gas phase comparison [Eisele, et al., submitted 2002] and the ACE-Asia multi-platform surface measurements [Masonis, et al., manuscript in preparation]. Here we focus on comparable instrumentation for measuring aerosol concentrations, size distributions and integral properties, optical properties, and aerosol chemical constituents. Each set of instruments has a different sampling frequency, but the data compared here has been merged into the same 1-minute data set.

With the exception of the complete high-resolution aerosol size distributions and associated aerosol thermal volatility (see below), data is available through the NASA TRACE-P website (ftp://ftp-gte.larc.nasa.gov/pub/TRACEP/merges) and the NSF/NCAR ACE-Asia website (http://www.joss.ucar.edu/ace-asia/dm/data_access_frame.html). Full aerosol size distributions and volatility measurements are available upon request from the principle investigators of the relevant research groups.

Aerosol concentrations—Concentrations of condensation nuclei (CN) were measured with a several CN counters: two TSI 3010's on the P3-B and two TSI 3760's on board the DC-8 and C-130. The CN counters' nominal 50% cut sizes depend on the temperature difference (ΔT) between the saturator and condenser chambers and the absolute temperature of the condenser chamber (not controlled and variable) and were reported as ~0.015 μm for all aircraft. The actual cut size can vary when environmental conditions (e.g. elevated instrument temperatures and/or changes in sample pressure) perturb normal condition required for saturation [Keady et al., 1986]. It should be noted that the ΔT was set to 17 deg C on board the P3-B and C-130 but was set to 21 deg C on the DC-8. This caused some variation in the actual cut size of the CN counters. Therefore, we expect CN concentrations on the DC-8 (higher ΔT) to have been greater

than on the other aircraft when there were significant quantities of small particles (aerosols with diameters at or near the instrument cut size) present. On each platform, one CN counter was operated at aircraft cabin temperature (~30±4 deg C) while the other sampled after heating the air stream to 350±10 deg C, driving off any volatile components and leaving a residual, refractory aerosol (RCN) that is frequently combustion derived [Moore et al., in press; Clarke, 1991; Clarke et al., 2001].

Additionally, all three platforms had a TSI 3025 for counting Ultrafine CN (UCN) with diameters greater than 0.003 μm. The P3-B UCN counter was modified to measure size distributions from 3 to 10 nm by replacing the laser light source with white light and adding a pulse height analyzer. This modification increased the detection volume, leading to coincidence counting (underestimating concentrations) when UCN were above several thousand #/cm^3. This problem does not occur for normal operation of the standard UCN counter until ~100,000 #/cm^3 and, therefore, we expect that often the P3-B UCN concentrations could have been less than those measured on the other platforms due to coincidence counting. The instrument was deployed to provide a measurement of the presence, or lack of, aerosols with diameters between 3 and 4 nm for studies of homogeneous nucleation in Asian plumes [Weber et al., 2003]. Under "cleaner" conditions such as during the ACE-1 experiment, this modified UCN counter was in good agreement with other CN and UCN counters [Weber et al., 1999].

The DC-8 UCN and CN counters were operated downstream of a critical orifice in order to maintain a constant pressure of ~213 mbar whereas those on the C-130 and P3-B operated at near ambient sample pressure that varied with altitude. All CN measurements are reported after scaling to standard temperature and pressure (STP, T=298.15 K and P=1013 mbar) and are therefore similar to mixing ratios.

Aerosol optical properties—The aerosol light scattering coefficients (σ_{sp}) and hemispheric backscattering coefficients at three wavelengths (450, 550, and 700 nm) were measured with a TSI 3563 integrating nephelometer on all aircraft and corrected for truncation errors inherent in the instrument as per T. Anderson et al. [1996]. The nephelometer RH was typically below 45% and therefore the reported scattering coefficients are considered "dry". Particle absorption coefficients (σ_{ap}) were measured on each platform with a Radiance Research Particle/Soot Absorption Photometer (PSAP) at a wavelength of 565 nm (550 nm on board the C-130). PSAP data was corrected according to Bond et al. [1999] and the reported absorption coefficients are also considered "dry". The dominant aerosol absorber (in the visible wavelengths) is black carbon (BC) [Heintzenberg, 1982], although dust and organic aerosols can contribute. The sub-μm aerosol absorption component (where the majority of coarse mode dust has been excluded) is usually directly related to BC concentrations [Clarke et al., submitted 2002].

On the DC-8 a single nephelometer operated continuously while on the P3-B, a 30 lpm impactor (aerodynamic size cut of 1.0 μm, fabricated NOAA, PMEL, Seattle WA) was periodically switched in line to assess scattering and absorption by sub-μm aerosols. The C-130 had two nephelometers and two PSAP's, one set of which always had a 1.0 μm impactor in line, resulting in continuous measurements of both total and sub-μm scattering and absorption. Aerosol optical properties are reported at ambient pressure and temperature (not STP). The measured "dry" scattering coefficients will often be greater at ambient RH due to hygroscopic growth [Tang and Munkelwitz, 1993; Hagen et al.,

1989]. The effect of hygroscopic growth on measured absorption coefficients is not well defined.

Aerosol size distributions—Aerosol size distributions were measured with a variety of instruments on each platform. The smallest aerosols ($0.007<D_p<0.25$ μm) were measured with a custom-made Radial Differential Mobility Analyzer (RDMA, [Zhang et al., 1995]) on the P3-B and C-130. The DC-8 used a TSI 3936 Scanning Mobility Particle Sizer (SMPS) for measuring size distributions for particles with $0.01<D_p<0.25$ μm. Larger particles ($0.1<D_p<20.0$ μm) were sampled on board the P3-B and C-130 with a custom-made Laser Optical Particle Counter (OPC) (Clarke, 1991). Both the DMA's and OPC's were operated inside the aircraft near ambient pressure, but at cabin temperatures. The size distributions were measured after mixing with dessicated air to achieve "dry" conditions with sample RH usually less than 35%. This reduced the impact of water uptake by the aerosol on the measured size so that the distribution better reflected the soluble and insoluble aerosol components. During horizontal legs the DMA's and OPC's operated with a thermal pre-conditioning unit that cycled the aerosol through 150 deg C and 350 deg C to drive off the volatile and semi-volatile aerosol constituents, allowing inference of aerosol chemistry [Moore et al., in press; Clarke, 1991; Smith and O'Dowd, 1996]. Even though volatility measurements were consistent on the P3-B and C-130, only the unheated size data will be included in the comparisons discussed here. The DC-8 measured particle size distributions with a wing mounted Particle Measuring Systems (PMS) Passive Cavity Aerosol Spectrometer Probe (PCASP) for $0.11<=D_p<=3.0$ μm. The PCASP cavity was heated to an elevated but unmeasured temperature to result in somewhat "dry" size distributions. PMS Forward Scattering Spectrometer Probes (FSSP-300, Droplet Measurement Technologies modified) were mounted on the wings of each aircraft and measured "ambient" (RH, P, and T) size distributions for particles with $0.3<D_p<20.0$ μm. All of the optical particle sizing instruments (OPC's, PCASP, and FSSP's) were calibrated using polystyrene latex spheres (PSL, index of refraction = 1.59 @ 589 nm) and glass beads (index of refraction = 1.56 @ 589 nm). Therefore, the particle diameters are effective optical sizes (size of a PSL sphere that scatters the same amount of light as the measured aerosol particle) under the sample conditions experienced.

We have selected two size ranges for calculating aerosol integral properties corresponding to the aerosol accumulation and coarse modes. For the "dry" sizing instruments (OPC's and PCASP), these size ranges are from 0.1 to 0.75 μm (accumulation mode) and 0.75 to 20.0 μm (coarse mode). The PCASP only measures up to 3.0 μm, so only PCASP accumulation mode integrals are presented. This size cut (0.75 μm) was chosen to match the 1 μm aerodynamic cut size of the impactor. An aerodynamic diameter of 1.0 μm typically corresponds to an effective optical diameter of 0.75 μm (assuming a dry sulfate aerosol of typical density and index of refraction, etc.). Also, 0.75 μm effective optical diameter is near the minimum observed between the accumulation and coarse modes in the "dry" size distributions (the actual position can vary). The FSSP separation between the accumulation and coarse modes was selected to be 1.0 μm since this was usually the observed position of the minimum between the two modes (the FSSP's are measuring at ambient RH and are not "dry"). It should be noted that "dry" size distributions (OPC's and PCASP) often swell to larger diameters at ambient RH due to hygroscopic growth [Tang and Munkelwitz, 1993]. Size

distributions and integral properties are reported as measured at ambient pressure and temperature (not STP) except when compared to aerosol chemistry measurements (as noted below).

Aerosol chemistry—On board the C-130 and P3-B, soluble aerosol chemical constituents were measured with a new Particle Into Liquid Sampler (PILS) [Orsini et al., in press 2003; Weber et al., 2001]. The PILS had a 50% size cut of ~1.3 μm and typically provided data every 5 minutes. Aerosol chemical constituents were collected with bulk filters on the DC-8. Soluble aerosol species for sizes up to ~7 μm were measured after aqueous extraction and IC analysis [Dibb et al., submitted 2002]. The average filter collection time varied with altitude and was about 6 minutes below 1 km, 9 minutes between 1 and 6 km, 13.5 minutes between 6-9 km, and 16 minutes above 9 km. Additionally, a new technique was employed on board the DC-8 utilizing a mist chamber and a dual ion chromatography analytical system (MC/IC) that sampled trace acidic gases and measured "fine" aerosol sulfate every ~2-4 minutes [Dibb et al., submitted 2002]. The 50% size cut for the "fine" aerosol sulfate has yet to be determined, but preliminary analysis suggests that it is near 2.7 μm. Aerosol chemical constituent concentrations are reported at STP conditions, similar to mixing ratios.

Because the DC-8 filter samples measured chemical constituent concentrations up to ~7 μm while the PILS instrument had a 50 % size cut of ~1.3 μm, discrepancies between aerosol chemical components associated with the largest, coarse mode aerosols are expected (Na, Cl, Mg, Ca, etc.). It is also expected that disagreement between the PILS and filter samples for the aerosol chemical constituents normally associated with the accumulation mode (SO_4, NH_4, and NO_3) will be relatively small. However, recent data from the ACE-Asia experiment has shown that these components can be associated with the larger aerosol sizes, particularly when in the presence of "aged" dust aerosol [Kline et al., submitted 2002, B. Huebert, personal communication].

Inlet losses—Each aircraft had its own set of sample inlets and associated inlet losses that are most severe for the largest particles (super-μm). The C-130 and P3-B inlets were kept isokinetic during flight by adjusting flows as flight parameters changed. The P3-B aerosol measurements were made through a solid diffuser inlet (SDI). ACE-Asia (C-130) measurements were made with a new Low Turbulence Inlet (LTI) that has been shown to pass coarse mode particles more efficiently, although corrections for size dependant particle enhancements by the LTI still need to be made. Corrections to the size distributions sampled behind the SDI and LTI are reported in the NSF PELTI Final Report [B. Huebert et al., 2000, available on-line at http://raf.atd.ucar.edu/Projects/PELTI/] and at 3 μm, after accounting for both inlet effects and plumbing losses, volume concentrations should increase by 25% and 11% for the SDI and LTI respectively.

The DC-8 had several aerosol sampling inlets for each group. Aerosol chemistry measurements were made through a forward facing tandem probe arrangement [Dibb et al., submitted 2002] while the other aerosol parameters were sampled through either a forward facing SDI similar to the P3-B (nephelometer and PSAP) or a "scoop" inlet (CN counters, SMPS system). The latter does not efficiently pass super-μm particles, but its advantage is in reducing droplet shatter for measurements within clouds. All of the various DC-8 inlets have different and uncharacterized passing efficiencies for the super-

μm aerosol that will affect measurements of the coarse mode particles and are one of the largest sources of differences between some measurements.

Additional Parameters—Most aerosol measurements are extensive parameters (σ_{sp}, σ_{ap}, RCN, CN, and UCN concentrations, aerosol integral properties, and chemical constituent concentrations, etc.) that vary with altitude, concentration, etc. We will also report comparisons of several derived, intensive variables that vary with aerosol properties but not concentration. Significant changes in the latter generally reflect differing air mass characteristics.

The aerosol single scatter albedo (ω_0) is the ratio of aerosol light scattering to aerosol total light extinction (scattering plus absorption) and defined by:

$$\omega_0 = \sigma_{sp}/(\sigma_{sp} + \sigma_{ap})$$

This quantity is of significant interest to those in the aerosol remote sensing and radiative transfer communities [Russell et al., 2002]. Since variations in ω_0 below unity are driven by absorption, we will report values of the aerosol co-albedo (the ratio of aerosol absorption to aerosol extinction, or $1-\omega_0$) as well. The RCN ratio is the ratio of refractory CN (CN remaining after heating to 350 deg C) to total CN and regions with elevated RCN ratios (in the absence of significant concentrations of dust or sea salt) are likely to have been influenced by combustion/continental emissions [Moore et al., in press; Clarke et al., 1997]. Low values of this parameter indicate the dominant presence of a more volatile aerosol number. Ultra-fine CN (UF) concentrations are operationally defined as the difference between the UCN and total CN concentrations (UF = UCN – CN) and are the number of particles with diameters between 0.003 μm and the CN cut size (~0.015 μm). Large UF concentrations often imply recent nucleation. We also report a derived average effective diameter to assess how well the OPC, PCASP, and FSSP instrumentation are sizing relative to each other. This quantity is derived from the integral properties through the following equation:

$$\text{Average } D_{eff} = (6 \times V)/A$$

where V is the integral volume and A is the integral surface area.

Instrument Uncertainties—All of the instruments are prone to uncertainties due to errors in measured flow rates, pressures, temperatures, actual cut sizes, and calibrations, among other factors. The NASA TRACE-P (both P3-B and DC-8) aerosol instrumentation and PI provided instrument uncertainties are found on-line at http://www-gte.larc.nasa.gov/trace/TP_Investigator_Measurements.htm. We have assumed here that nominal accuracy for sub-μm physical measurements (scattering, absorption, CN, DMA and PCASP/OPC accumulation mode distributions and integrals) to be on the order of 10%, such that differences between instruments and platforms sampling similar air masses are expected to be less than 20% for these measurements. These uncertainties for the DMA and PCASP/OPC are for the integral accumulation mode number. Despite having the same 1-minute time stamp, DMA and OPC measurements on the aircraft are not "synchronous" due to the temperature cycling associated with these instruments (each DMA scan occurs every ~6 minutes, each OPC scan occurs every ~3 minutes). This adds an additional source for discrepancy, particularly when sampling in inhomogeneous air masses. Coarse mode OPC measurements for the largest aerosol are prone to poor counting statistics and inlet/plumbing losses and uncertainties for these are estimated to be ~15-20%. FSSP coarse measurements are also affected by poor statistics and other associated

uncertainties are estimated to be as high as 20% (NSF PELTI Final Report [Huebert et al., 2000]) for the number concentration. Uncertainties for FSSP derived surface area and volume concentrations would be larger than this for diameters greater than 1 μm due to the D_p^2 and D_p^3 terms utilized in converting number to surface area and volume, respectively. Sizing errors arising from FSSP calibration and assumed index of refraction can be larger since the FSSP measures forward scattered light (not side scatter like the PCASP and OPC) that is more sensitive to changes in these parameters relative to the calibration aerosol and that the FSSP tends to oversize in the 3 to 10 μm diameter size range [Reid et al., submitted 2002] so that some differences are expected between FSSP data and the other sizing instruments in this range. We estimate uncertainties in FSSP integral coarse measurements to be ~25-35%. Although each instrument is affected differently by each of these issues, a full discussion of these effects is complex and beyond the scope of this paper. For the remainder of this paper, we have selected threshold of 25% (30-35% for the FSSP's) to determine if the difference between measurements is considered reasonable.

3. Inter-comparison Flights:

Figure 1 shows the flight tracks for the five inter-comparison flights and the locations of the horizontal legs during the inter-comparison time periods discussed here. Inter-comparison flights 1, 2, and 5 (TRACE-P DC-8 and P3-B) are shown in figures 1a, 1b, and 1e, respectively. Flight 1 occurred in the marine boundary layer (MBL) to the northwest of Guam (remote from the Asian continent, presumably in "clean" air) on the ferry flight to Hong Kong. Flight 2 occurred downwind of the main Japanese Island of Honshu in a region of strong outflow. The flight 5 inter-comparison legs were to the northeast of the Hawaiian Islands on the ferry flight to California in air that was remote from any continents and presumably representative of "clean" conditions. Flights 3 and 4 (ACE-Asia C-130 and TRACE-P P3-B) are shown in figures 1c and 1d, respectively, and occurred in a region of strong Asian outflow in the vicinity of Japan. Table 1 contains a listing of all the comparison flights, which platforms were being compared, their locations, dates, number of horizontal legs, and leg information (altitude, ambient RH, leg times, and primary aerosol constituents).

A time series of the ambient, nephelometer, and OPC RH (FSSP RH is ambient), and aircraft altitudes are shown in figure 2 (a thru e for flights 1 thru 5, respectively) for the 5 flights and reveal the wide range of conditions encountered. In all cases throughout this paper where ambient RH is discussed, it is the RH over water (not ice). The low and stable instrument RH's shown in this figure confirm that measured optical properties and OPC size distributions were "dry" (instrument RH not over 40%, except in the warm MBL to the northeast of Hawaii—flight 5, and in the warm MBL to the northwest of Guam—flight 1). Therefore, observed differences in these parameters are not due to differences in water uptake by the aerosol. Also shown in figure 2 are periods influenced by cloud penetrations that might affect the quality of the data comparison (various groups may have edited their data differently and both aircraft may not have flown through similar clouds).

4. Horizontal Leg Averaged Data:

Horizontal leg averages for aerosol physical properties (concentration, aerosol optics, and integral properties from size distributions) and soluble chemical constituent concentrations are summarized in tables 2 and 3, respectively. These tables will be referred to throughout this paper and contain the mean values of the various parameters measured for each horizontal leg and also the standard deviations for each measurement (reflecting the variability encountered). The first line in each table cell contains the P3-B mean value and the mean variance in parenthesis (designated by P in the tables). The second line is the same, except the entries are for the second platform (C-130 or DC-8, labeled C and D in the tables, respectively). The third line contains the ratios of the means and standard deviations (in parenthesis) for the C-130 and DC-8 data relative to those measured on the P3-B. The number of 1-minute data points that were utilized in calculating the means and standard deviations are included on the fourth entry (in brackets).

The majority of the continuous physical measurements (CN concentrations, scattering and absorption coefficients, and FSSP measurements) have means and variances calculated only when there were simultaneous measurements on both platforms, resulting in the same number of 1-minute data for each aircraft. Time periods where there were no data from one or both of the platforms are not included. For the more intermittent OPC, DMA, and aerosol chemistry measurements, data was included in the averages regardless of whether or not there were coincidental measurements on both platforms since these instruments were not simultaneous nor continuous, although this may introduce biases in the leg averaged data. For these measurements, the number of data points from each platform are reported in brackets on the fourth line of each entry of tables 2 and 3, with the P3-B number of data points being reported first. Inter-comparison legs where data was not available from one of the platforms for the entire leg are marked by "No data" and corresponding "N/A" for the platform where data was available.

When the ratios of the means and variances for compared measurements are near 1.0 (±25%) they are underlined in tables 2 and 3 and are considered here as reasonable agreement. Those legs where the ratios of the means and variances are greater than 1.35 or less than 0.65 represent less favorable comparisons and are marked with an asterisk.

5. Data Presentation Format:

In order to simplify data evaluation by the reader, we first list pertinent leg-averaged data in a bulleted format within each section, including leg number, start and stop times, altitude, and ambient RH values, followed by a comparison of the mean values from the two aircraft for the parameter being discussed. Due to the large number of soluble aerosol chemical species measured during these field campaigns, we refer to table 3 rather than listing the leg averages during the comparison of aerosol chemistry. Systematic discrepancies and/or differences in measurements greater than 35% will be highlighted by an asterisk and addressed later in the discussion. We will then show time series of the compared measurements to see if trends in the data are duplicated despite any discrepancies in the absolute values.

In each data section, we will present comparisons between the ACE-Asia C-130 and TRACE-P P3-B aircraft first since their payloads are more similar. Next, favorable

comparisons between the TRACE-P DC-8 and P3-B platforms will be shown, followed by presentation of data from the two TRACE-P aircraft where there is less agreement.

6. Aerosol Optics:

6.1 ACE-Asia C-130 and TRACE-P P3-B comparison

6.1.1 Inter-comparison flight 4

The leg-averaged values of aerosol optical properties (table 2) were:

- Leg 1 (02:12-03:10 UTC) [0.2 km] ambient RH 63-78%
  * P3-B total σ_{sp} ~22% < C-130
  P3-B sub-μm σ_{sp} ~2% < C-130
  * P3-B total σ_{ap} ~17% < C-130
  P3-B co-albedo ~1% > C-130
- Leg 2 (03:12-03:40 UTC) [0.6 km] ambient RH 75-85%
  * P3-B total σ_{sp} ~23% < C-130
  P3-B sub-μm σ_{sp} ~3% > C-130
  * P3-B total σ_{ap} ~23% < C-130
  P3-B co-albedo ~2% > C-130
- Leg 3 (04:30-04:51 UTC) [1.7 km] ambient RH 3-25%
  * P3-B total σ_{sp} ~24% < C-130
  P3-B sub-μm σ_{sp} ~22% > C-130
  * P3-B total σ_{ap} ~45% < C-130
  P3-B co-albedo ~23% > C-130

Total and sub-μm aerosol light scattering coefficients (λ = 550 nm) for this flight (fig. 3a) were measured continuously on the C-130 while the P3-B periodically switched between the two. The comparison time period covered a wide range of ambient relative humidity but nephelometer RH never exceeded 30% (fig. 2d). The sub-μm scattering coefficients (table 2, fig. 3a) trended together and generally agreed to within 5% of each other over an order of magnitude of values with no systematic difference observed between the two platforms. In contrast, the total scattering coefficients (table 2, fig. 3a) on the P3-B were systematically between 20-25% lower than on the C-130, except in time periods when the aircraft were above the inversion and there were less coarse aerosol (sub-μm and total scattering nearly equal, e.g. profile at 4.0 hrs and leg 3). Despite that the total scattering coefficients were generally within 25% of each other (i.e. "good agreement"), this systematically lower values for the P3-B total scattering data compared to the C-130 data will be addressed in the discussion.

The aerosol total absorption coefficients for this flight (fig. 3b, no sub-μm absorption measurement for the C-130) trended closely but were systematically lower by 17-44% on the P3-B than on the C-130 (table 2, fig. 3b). The P3-B total absorption was ~10% higher than the sub-μm absorption for the majority of data points, indicating some absorption from the coarse mode aerosol.

Total ω_0 values were near ~0.9 (co-albedo ~0.1) for the majority of measurements and agreed within 5% of each other (fig. 3c). There were no sub-μm ω_0 values from the C-130 to compare to, but the values from the P3-B ranged from ~0.87 to 0.89. Total ω_0 values for leg 3 were highly variable on both aircraft due to scattering and absorption

coefficients at or near instrumental noise levels of ~0.05 Mm^{-1} for scattering and ~0.2 Mm^{-1} for absorption.

6.2 TRACE-P DC-8 and P3-B comparison

6.2.1 Inter-comparison flight 2

The leg-averaged values of aerosol optical properties (table 2) were:

- Leg 1 (00:01-00:30 UTC) [5.2 km] ambient RH 9-50%
  P3-B total σ_{sp} ~10% < DC-8
  * P3-B total σ_{ap} ~factor of 2 < DC-8
  P3-B co-albedo ~factor of 1.8 < DC-8

Total and sub-μm light scattering coefficients (no sub-μm measurements on the DC-8) during comparison flight 2 (fig. 3d) from both aircraft showed a gradient in scattering with higher values near the end of the leg. Ambient RH (fig. 2b) was very dry (~9%) initially and increased to 50% at the end of the leg, exhibiting the same structure as the total aerosol light scattering. However, both nephelometer RH's remained at ~1% for the entire leg (fig. 2b), confirming that the gradient in measured scattering was not related to water uptake. Sub-μm scattering was only ~60% of the total (fig. 3d), implying a significant contribution to total scatter from super-μm aerosols.

Total and sub-μm absorption coefficients (fig. 3e) were about a factor of 10 lower than the previously discussed flight. The little change between total and sub-μm absorption reflected absorption due to the presence of sub-μm black carbon (BC). The P3-B absorption data also showed a steady increase over time consistent with the scattering data. The DC-8 absorption data was typically higher and more variable than on the P3-B and had less evidence of any trend.

The total and sub-μm ω_0 values derived from P3-B data were ~0.94 and ~0.87 (co-albedos of 0.06 and 0.13), respectively (fig. 3f). This value of sub-μm ω_0 was similar to the ω_0 values from the previously discussed flight that had little coarse scattering. This suggests a similar pollution aerosol on both flights but with less absorbing coarse aerosol on this one. The DC-8 values of ω_0 appeared to be unreasonably low and were more variable than on the P3-B due to the variability in DC-8 absorption (see discussion).

6.2.2 Inter-comparison flight 1

Flight 1 occurred in the "clean" MBL, providing an opportunity to compare DC-8 and P3-B measured aerosol optical properties under different conditions than the data presented for flight 2. The ambient and nephelometer RH were relatively high on this flight (~80% and ~50%, respectively—see fig. 2a) with more coarse sea salt sampled (see chemistry section) than during flight 2.

The leg-averaged values of aerosol optical properties (table 2) were:

- Leg 1 (01:10-01:30 UTC) [0.2 km] ambient RH 75%
  * P3-B total σ_{sp} ~factor of 4 > DC-8
  P3-B total σ_{ap} ~31% > DC-8
  P3-B co-albedo ~factor of 3 < DC-8

After the MBL leg and above the inversion (~2.0 km), the air was dry (~20% ambient RH), aerosol scattering was low, and there was good agreement within ~5% between the two platforms (fig. 3g). However, within the MBL where the RH was higher (~75%), DC-8 scattering was only ~23% (table 2, fig. 3g) of the P3-B data, although both sets of data trend together. This large discrepancy appears related to poor inlet performance on the DC-8 at low altitudes and will be discussed in more detail.

The absorption data on the two platforms were quite low at ~0.75 Mm^{-1} (already a surface value), suggesting "clean" conditions (low BC), and approached the noise limit for 1-minute averages (fig. 3h). Even so, the absorption values were similar over the comparison period and leg averaged values (see above and table 2) were within 30% of each other, despite the spike (~1.4 hrs) observed in the P3-B absorption data. This spike corresponded to enhancements in CN and RCN, NO and NO_y, and SO_2, suggesting that the aircraft flew through a ship plume. After removing this data point, the absorption coefficients were within 20%.

Total ω_0 values for both aircraft are shown in figure 3i and the DC-8 values were systematically lower than those on the P3-B. Values measured on the P3-B were generally ~0.99 (corresponding to a co-albedo of 0.01), in line with other values in the "clean" MBL reported in the literature [Russell et al., 2002; Dubovik et al., 2002]. In this case the lower aerosol single scatter albedo (and corresponding higher co-albedo) measured on the DC-8 was due to the much lower scattering values.

7 CN Concentrations:

7.1 ACE-Asia C-130 and TRACE-P P3-B comparison

7.1.1 Inter-comparison flight 4

The leg-averaged values of RCN and CN concentrations and RCN ratios were:

- Leg 1 (02:12-03:10 UTC) [0.2 km] ambient RH 63-78%
  P3-B RCN ~9% < C-130
  * P3-B total CN ~50% < C-130
  P3-B RCN ratio ~74% > C-130
- Leg 2 (03:12-03:40 UTC) [0.6 km] ambient RH 75-85%
  P3-B RCN ~4% < C-130
  * P3-B total CN ~45% < C-130
  P3-B RCN ratio ~74% > C-130
- Leg 3 (04:30-04:51 UTC) [1.7 km] ambient RH 3-25%
  P3-B RCN ~5% > C-130
  P3-B total CN ~3% < C-130
  P3-B RCN ratio ~10% > C-130

RCN concentrations exhibited agreement within 10% between the C-130 and the P3-B (table 2, fig. 4a). However, both the total CN and UCN concentrations on the P3-B were systematically lower than those on the C-130 (fig. 4a and b). Despite the disagreement in absolute concentrations, the measurements trended together and exhibited the same structure. At higher altitudes, all similar measurements were in better agreement (e.g. 4.0 hrs GMT and leg 3); leg 3 CN concentrations were within 6%. UF concentrations (difference between UCN and CN) were essentially zero for both platforms, suggesting no particles below 15 nm.

Since the C-130 CN concentrations were much higher and the RCN concentrations were virtually the same as on the P3-B, the C-130 RCN ratio (fig. 4c) was lower than measured on the P3-B for legs 1 and 2 (leg 3 values are comparable). However, the RCN ratios on both aircraft trended together and showed the same structure. Leg 1 and 2 values were at or near the 25% level for classifying the comparison as good and any discrepancy was due to the behavior of the total CN concentrations on either the P3-B or C-130.

7.2 TRACE-P DC-8 and P3-B comparison

7.2.1 Inter-comparison flight 1

The leg-averaged values of the RCN and CN concentrations were:

- Leg 1 (01:10-01:30 UTC) [0.2 km] ambient RH 75%
  P3-B RCN ~1% < DC-8
  P3-B total CN ~17% < DC-8
  P3-B RCN ratio ~18% > DC-8

RCN and CN concentrations for the DC-8 and P3-B are shown in figure 4d and revealed agreement to within 17% between the two aircraft. Some variability in CN might be a result of clouds at about 1.57 and 1.68 hrs (fig. 2a) and a probable ship plume near 1.4 hrs (see above discussion of absorption data for this flight—section 6.2.2). Small-scale features like these could have been intrinsically different as measured on both platforms. Shown in figure 4e are the DC-8 and P3-B UCN concentrations for the same time period and there was agreement between these two measurements to within 5%. UF concentrations were negligible for both aircraft indicating the absence of significant numbers of small particles.

Although differences were variable between the RCN ratios on the two aircraft (fig. 4f), there was a tendency for larger differences at lower concentrations. The RCN ratios indicated that significant fractions (50-75%) of the total CN were refractory during this MBL leg. Also, the structure in RCN ratio observed on the climb out of the MBL (starting at ~1.5 hrs) was represented in both measurements, even though the absolute values disagree.

7.2.2 Inter-comparison flight 5

Leg-averaged values of RCN and CN concentrations were:

- Leg 1 (06:03-06:25 UTC) [5.2 km] ambient RH 12.5%
  * P3-B RCN ~factor of 3 < DC-8
  * P3-B total CN ~50% < DC-8
  * P3-B RCN ratio ~factor of 2 > DC-8
- Leg 2 (07:00-07:19 UTC) [0.2 km] ambient RH 50%-nearly 100%
  P3-B RCN ~5% < DC-8
  P3-B total CN ~30% < DC-8
  P3-B RCN ratio ~25% > DC-8

Figure 4g shows the RCN and CN concentrations for the DC-8 and P3-B for flight 5. There were two comparison legs during this flight, with a descent profile between them (fig. 2e). The vertical profile had a cloud penetration from 1-2 km altitude and data

from that time period has been removed. Within the MBL (18.7 to 19.4 hrs), CN and RCN concentrations agreed well and their structure was generally replicated on both platforms. UCN concentrations were within 10% on the two aircraft and also trended together (fig. 4h). The agreement in these parameters started at ~18.6 hrs, corresponding to an altitude of ~4 km (fig. 2e). Above this altitude (including the 5.2 km leg), the P3-B CN and UCN concentrations were systematically lower (~65%) than those measured on the DC-8 (see discussion). P3-B UCN values were also less than CN by 10-15% and probably reflected flow uncertainties in one or both instruments or temperature effects. P3-B RCN concentrations were within 5% to 20% of the DC-8 measurements, depending on what portion of the high altitude leg was analyzed. UF concentrations were negligible for both aircraft during the two legs.

During leg 1 (5.2 km altitude), the DC-8 RCN ratio was approximately twice the P3-B value (fig. 4i), but both values were less than 0.1 and revealed a large volatile aerosol fraction. This is frequently observed in the "clean" FT over the remote Pacific Ocean. RCN ratios for both aircraft in the MBL were above 0.5, indicating a much less volatile aerosol at this altitude. On the descent profile between the two legs (from 18.5 to 19.0 hrs), there was considerable variability in both measurements and in general, the two trended together. The large difference in RCN ratios at high altitude was driven primarily by the differences observed in RCN and CN concentrations.

8 Aerosol Size Distributions and Integral Properties:

8.1 ACE-Asia C-130 and TRACE-P P3-B comparison

8.1.1 Inter-comparison flight 3

It should be noted that in the following, the number of distributions were not equal on the two platforms (leading to possible biases in the averages) and are given in table 2. The leg-averaged values of selected DMA, OPC, and FSSP integrals were:

- Leg 1 (00:54-01:33 UTC) [0.2 km] ambient RH 50-75%
  *P3-B DMA integral number ~factor of 1.9 < C-130
  P3-B OPC integral accumulation mode surface area ~8% < C-130
  * P3-B OPC integral coarse mode surface area ~33% < C-130
  * P3-B FSSP integral coarse mode surface area ~81% < C-130
- Leg 2 (01:41-02:01 UTC) [2.5 km] ambient RH 8%
  P3-B DMA integral number ~22% > C-130
  P3-B OPC integral accumulation mode surface area ~17% < C-130
  * P3-B OPC integral coarse mode surface area ~7% < C-130
  * P3-B FSSP integral coarse mode surface area ~factor of 3 < C-130
- Leg 3 (02:09-02:27 UTC) [0.9 km] ambient RH 60-67%
  P3-B DMA integral number ~3% > C-130
  P3-B OPC integral accumulation mode surface area ~9% < C-130
  * P3-B OPC integral coarse mode surface area ~12% < C-130
  * P3-B FSSP integral coarse mode surface area ~33% > C-130
- Leg 4 (02:32-02:38 UTC) [0.1 km] ambient RH 44%
  P3-B DMA integral number ~6% > C-130
  P3-B OPC integral accumulation mode surface area ~8% > C-130
  * P3-B OPC integral coarse mode surface area ~33% < C-130
  * P3-B FSSP integral coarse mode surface area ~8% > C-130

- Leg 5 (03:00-03:24 UTC) [0.9 km] ambient RH 60-75%
  P3-B DMA integral number ~22% > C-130
  P3-B OPC integral accumulation mode surface area ~1% < C-130
  * P3-B OPC integral coarse mode surface area ~6% < C-130
  * P3-B FSSP integral coarse mode surface area ~37% > C-130

Shown in figure 5 are the combined unheated number distributions from the DMA's and OPC's from both aircraft. The main figure shows the distributions with the concentrations (y-axes) on a log scale, showing the distributions for the full range of diameters while the insets show concentrations on a linear scale, allowing for a better comparison between the four instruments. The distributions showed very good agreement in both shape and concentration between the DMA and OPC on each platform and between the two aircraft. Log-normal fits were performed on the combined OPC/DMA accumulation mode distributions. The number geometric mean diameters for the two distributions were 0.181 μm for both aircraft with standard deviations (σ_g) of 0.564 and 0.511 for the P3-B and C-130, respectively. Fitted amplitudes were 780 and 772 #/cm^3 for the P3-B and C-130. In both cases the fits were good, with R^2 values of 0.988 (P3-B) and 0.982 (C-130). Observed differences in the leg-averaged data may be due to a variety of factors including the non-synchronous nature of the measurements (see instrument section).

OPC accumulation mode integral surface areas for the C-130 and P3-B (fig. 6a) exhibited good agreement over the wide range of surface areas measured (from ~10 to ~300 μm^2/cm^3) and over significant gradients. The highest surface areas were found on legs 1, 3, 4, and 5 in the MBL below 1.5 km altitude (fig. 2c). The average effective diameters for the two OPC's (not shown) were both about 0.25 μm (differences less than 5%) and persisted over the entire comparison period in spite of the gradients observed in the accumulation mode surface areas.

Generally, greater variability was evident in the measured coarse particle surface area (fig. 6b) due to the much lower count statistics for the larger sizes, especially over short time scales. The C-130 OPC coarse mode surface area values were frequently higher than the P3-B data. This difference was consistent with the observed discrepancy between the total aerosol light scattering measured on the aircraft during flights 4 and 5, where P3-B values were between ~10% and 25% lower (table 2). The higher C-130 values were possibly due to enhancement in the largest aerosol due to the LTI inlet (see discussion).

The FSSP's are wing mounted probes and not affected by inlet and plumbing losses. Also, since the FSSP size distributions are measured at ambient RH (not "dry" like the OPC's), FSSP integral properties should be greater than corresponding OPC measurements when ambient RH is "high" (usually more than 45%). The actual RH at which we expect the "dry" and "wet" measurements to diverge is strongly dependent upon aerosol composition [Tang and Munkelwitz, 1993]. Portions of this flight where FSSP coarse mode surface areas were higher than the OPC measurements (fig. 6b) occurred predominately during periods where the ambient RH was above 55% (fig. 2c), with the greatest differences corresponding to the highest RH.

P3-B FSSP coarse mode surface areas during the first two legs were lower than both the C-130 FSSP measurements and the OPC data as well and suggesting P3-B FSSP

data for these two legs were not accurate. There was a lot of variability in the coarse mode average effective diameter for all four instruments (not shown). However, this parameter was generally around 2.5 μm for both OPC's and agreement was within ~15%. The P3-B FSSP average effective diameter was also ~2.5 μm until approximately 26.0 hrs when it increased to ~4.9 μm when the ambient RH increased to 64% (fig. 2c) and we would expect hygroscopic growth to play a role. At ~26.5 hours when the aircraft entered drier air, the P3-B FSSP effective diameter decreased until ~26.9 hours, where the RH increased and it is again ~4.9 μm. The C-130 FSSP coarse mode surface area and average effective diameter were highly variable through out, but generally exhibited the same behavior as the P3-B FSSP (growth to larger sizes during legs with higher ambient RH).

Shown in figure 6c are leg averaged surface area distributions for leg 5 (RH ~70%) and they exhibited good agreement between the two OPC's for both the accumulation and coarse modes (below 8.0 μm, counting statistics get progressively lower at larger sizes). The FSSP coarse mode distributions revealed modest agreement with each other, except below 1.0 μm. Both FSSP distributions had greater amplitudes and were at larger sizes in the coarse mode than the corresponding OPC distributions, consistent with hygroscopic growth. The P3-B FSSP distribution was clearly not capturing the majority of the accumulation mode.

8.2 TRACE-P DC-8 and P3-B comparison

8.2.1 Inter-comparison flight 2

The leg-averaged values of selected DMA, OPC, PCASP and FSSP integrals were:

- Leg 1 (00:01-00:30 UTC) [5.2 km] ambient RH 9-50%
  P3-B OPC integral accumulation mode surface area ~23% > DC-8 (PCASP)
  * P3-B FSSP integral coarse mode surface area ~90% > DC-8

The P3-B OPC and DC-8 PCASP accumulation mode surface areas exhibited agreement within 25% (fig. 6d) and trended towards higher values towards the end of the leg, consistent with aerosol optical properties (figs. 3d and e), but not due to a rise in RH and associated hygroscopic growth (fig. 2b). The average effective diameter derived from the PCASP and OPC agree within 1% (not shown) at ~0.26 μm and remained constant over the leg so that the increases in accumulation mode surface area are indicative of increases in concentration rather than aerosol size.

Coarse mode surface areas from the OPC (P3-B) and FSSP's (P3-B and DC-8) are shown in figure 6e. During the first portion of the leg (24.0 to 24.225 hrs) where the ambient RH was less than 10% (fig. 2b), the OPC and FSSP coarse mode integral surface areas from the P3-B agreed but the latter became ~67% higher than the OPC measurement after ambient RH increased above 25% (fig. 2b). However, the DC-8 FSSP coarse mode integral surface area was only about 20% of the P3-B values throughout the entire leg, but did show the same trend to larger values.

The OPC derived coarse mode effective diameter (not shown) was relatively constant at ~4.0 μm while the FSSP effective diameters (both P3-B and DC-8), showed a gradual increase presumably due to the increase in ambient RH and water uptake. Leg averaged surface area distributions for the four instruments (DC-8 PCASP and FSSP, P3-

B OPC and FSSP) are shown in figure 6f and the "dry" accumulation mode distributions (OPC and PCASP) exhibited good agreement in both shape and concentration. Again, the DC-8 FSSP distribution showed much less surface area in the coarse mode than either the P3-B OPC or FSSP, consistent with the integral values. The P3-B FSSP coarse mode distribution revealed more surface area and the presence of larger aerosols than the OPC, consistent with both hygroscopic growth and the loss of the largest particles due to plumbing/inlet losses.

8.2.2 Inter-comparison flight 1

The leg-averaged values of selected DMA, OPC, PCASP and FSSP integrals were:

- Leg 1 (01:10-01:30 UTC) [0.2 km] ambient RH 75%
  P3-B OPC integral accumulation mode surface area ~40% > DC-8 (PCASP)
  * P3-B FSSP integral coarse mode surface area ~factor of 1.95 < DC-8

The DC-8 integral PCASP accumulation mode surface areas (table 2, fig. 6g) were lower than OPC values measured on the P3-B (clouds excluded, ~1.6 to 1.75 hrs, fig. 2a). Most time on this MBL leg the ambient RH was ~75%, the OPC RH was near 30%, and the PCASP RH was an unknown intermediate value. Hence, hygroscopic effects cannot be used to explain the PCASP and OPC differences. Also, the P3-B measurements showed a general trend towards lower values during the MBL leg (1.2 to 1.65 hrs) while the PCASP surface area was relatively constant even though the average effective diameter (not shown) was similar (~0.33 μm for both PCASP and OPC). The ship plume evident in figures 3h and 4d is not as apparent in the OPC, PCASP, and FSSP measurements since these instruments measure the larger aerosol; ship plumes are predominantly comprised of particles with diameters less than the size range of these instruments.

In contrast to flight 2, the DC-8 FSSP coarse mode surface area was about twice that measured on the P3-B (fig. 6h). This difference in the DC-8 FSSP measurements between the "wet" MBL (this flight) and the "dry" FT (flight 2) is not well understood at present. The OPC coarse mode surface area was ~2/3 of the P3-B FSSP measurement while the aircraft were in the MBL (~1.2 to 1.6 hrs) and agreed after climbing to ~3 km in dry air. This difference is consistent with hygroscopic growth from "dry" to ambient conditions. Both P3-B measurements showed a general trend to smaller values from the beginning to the end of the MBL leg, unlike the DC-8 FSSP surface area data.

The coarse mode average effective diameter (not shown) exhibited good agreement between the two FSSP's with average values of ~5.0 μm, despite the discrepancy in integral surface areas (fig. 6h). The OPC coarse mode averaged effective diameter was less than this at ~2.5 μm, again consistent with water uptake by the aerosol. Figure 6i plots the DC-8 (PCASP and FSSP) and P3-B (OPC and FSSP) leg averaged surface area distributions for the MBL leg. PCASP and OPC distributions revealed good agreement below 0.6 μm. However, the FSSP's exhibited large differences between the two aircraft while the P3-B FSSP surface area distribution appeared to be more consistent with the OPC after allowing for hygroscopic growth of the aerosol.

9 Aerosol Chemistry:

9.1 ACE-Asia C-130 and TRACE-P P3-B comparison

9.1.1 Inter-comparison flight 3

The soluble aerosol chemical concentrations for the C-130 and P3-B are shown in figure 7 for comparison flight 3 (Na, Ca, Mg, Cl, NH_4, SO_4, and NO_3 are shown in figs. 7a, b, c, d, e, f, g, respectively) and leg-averaged concentrations are contained in table 3. Similar PILS instruments with the same cut sizes showed good agreement for the majority of species (see Orsini et al. [in press 2003] and Weber et al. [2001] for more details). The aerosol constituents usually associated with the coarse mode (Na, Cl, Ca, etc.) in general trended together and with the OPC coarse mode surface area (fig. 6b) and suggested the presence of sea salt and a nearly equal amount of Ca, indicating dust. Since soluble Ca is only a small fraction of dust (3-4 % [R. Arimoto, personal communication]), this implies that there was relatively more dust than sea salt sampled. The chemical species usually associated with accumulation mode aerosols (i.e. NH_4, SO_4, and often NO_3) agree to within ~30% (table 3) between the two aircraft over a wide range of concentrations and also trended together and with the measured OPC accumulation mode surface areas (fig. 6a).

9.2 TRACE-P DC-8 and P3-B comparison

9.2.1 Inter-comparison flight 5

The aerosol chemical constituent concentrations measured on the DC-8 and P3-B are shown in figure 8 and leg-averages are contained in table 3. Since the PILS instrument (P3-B) had a 50 % size cut of 1.3 μm and the filter samples (DC-8) were bulk aerosol measurements (D_p < ~7.0 μm), the large discrepancies for Na, Ca, Mg, and Cl are not surprising (figs. 8a, b, c, and d, respectively). Sodium concentrations in the MBL were ~3-5 $\mu g/stdm^3$ (measured on the DC-8), much higher than in the previously discussed flight and suggested the presence of significant sea salt. DC-8 Ca concentrations were ~0.25 $\mu g/stdm^3$. Assuming that soluble Ca comprised ~3-4% of the dust concentration [R. Arimoto, personal communication], this implies ~8 $\mu g/stdm^3$ of dust during the MBL leg, roughly the same concentration as Na. At ~18.8 hrs during the descent profile (between 2.0 and 3.0 km), a layer of elevated Na and Ca concentrations was observed. This layer was located just above the inversion and cloud top level and in very dry air (fig. 2e). The Ca concentrations were higher than in the MBL and Na concentrations were ~1/2 those observed below, indicating a higher relative fraction of the coarse aerosol was mineral dust.

The NH_4, SO_4, and NO_3 concentrations (figs. 8e, f, and g, respectively) showed reasonable agreement between the two techniques on board both aircraft, although the DC-8 values were systematically higher than on the P3-B (especially for SO_4 and NO_3). This was most likely due to the association of these species with the larger coarse mode aerosol (dust and sea salt) and the PILS cut size (see discussion). In fact, the MC/IC "fine" sulfate concentrations measured on the DC-8 exhibited very good agreement with the PILS measured SO_4 (fig. 8f).

9.2.2 Inter-comparison flight 2

Aerosol soluble chemical concentrations for this flight are shown in figure 9 and leg-averaged values are listed in table 3. The ratios of the DC-8 to the P3-B measurements for a given species are also shown (black lines) in the figure. Again the

Na, Ca, Mg, and Cl concentrations (figs. 9a, b, c, and d, respectively) appeared enhanced by a factor of 3-5 on the DC-8 when compared to those on the P3-B due to the PILS cut size. The DC-8 measurements indicated concentrations of Na and Cl over a factor of 10 less than on flight 5 but Ca concentrations were ~2.0 $\mu g/m^3$, much higher than on flights 3 or 5 and implying a greater concentration of dust aerosol.

NH_4, SO_4, and NO_3 concentrations (figs. 9e, f, and g, respectively) exhibited much higher concentrations on the DC-8 than on the P3-B by approximately the same amount as those species usually associated with the coarse mode (~2-4 times the P3-B values). This is true even for the MC/IC "fine" and PILS sulfate concentrations (see discussion). Soluble aerosol species measured on both platforms exhibited a gradient from smaller to larger values near the end of the leg, consistent with aerosol light scattering and absorption coefficients (figs. 3d and e) and aerosol integral accumulation and coarse mode surface areas (figs. 6d and e).

10 Discussion:

The measurements discussed above showed general agreement in aerosol concentrations, size distributions, integral surface areas, effective diameters, optical properties, and chemical components. However, several systematic and/or occasionally large differences were observed and highlighted in the data. In the following sections, we will explore likely reasons for these discrepancies.

10.1 Aerosol Optics

Total aerosol scattering and absorption coefficients measured on the P3-B were systematically lower than on the C-130 by 11-25% during comparison flights 3 and 4 (time series and tabulated leg averages) while sub-μm scattering coefficients (no sub-μm absorption measurements on the C-130) agreed within 5-10% for most legs between the two aircraft. These two observations suggest that the differences in total optical properties observed were due to the probable enhancement of coarse particles seen by the LTI and/or losses in the SDI.

During the Passing Efficiency of a Low Turbulence Inlet (PELTI) experiment where the LTI (C-130) and SDI (P3-B) were flown on the same aircraft, total aerosol scattering measured behind the LTI was higher than SDI measurements by ~10-20% (for "dry" dust and "wet" sea salt cases, respectively). This is reported in the PELTI NSF Final Report (available on-line at http://raf.atd.ucar.edu/Projects/PELTI/) [Huebert, et al., 2000]. The C-130/P3-B total scattering difference generally ranges between the two cases measured during PELTI, not surprising since these flights frequently sampled air that contained both sea salt and dust with intermediate values of ambient RH. There were no aerosol absorption measurements during PELTI, but the enhancements observed for the C-130 data during ACE-Asia are consistent with enhanced dust concentrations (mildly absorbing) due to the LTI. Resulting single co-albedos were generally within 5% from the two aircraft (the systematic ~20% lower P3-B total scattering values were offset by the same systematic differences in total absorption).

Results for the DC-8/P3-B comparison of total optical properties (no sub-μm measurements on the DC-8) revealed different behavior under different sampling regimes. The DC-8 and P3-B scattering coefficients agreed within 10% aloft in the FT in "dry" air and in the presence of coarse dust aerosol. However, total scattering

coefficients measured on the DC-8 were lower than on the P3-B by a factor of 2 or more when sampling in the "clean" MBL with high ambient RH and relatively high concentrations of sea salt.

Comparison flight 5 provided an opportunity to sample in both "dry" FT air with dust and in the "wet" MBL with relatively more sea salt during the same flight. The aircraft altitude and total scattering (DC-8/P3-B) and sub-μm scattering (P3-B) are shown in figure 10a. During the high altitude leg, scattering coefficients on both aircraft were low (~0.7 Mm^{-1}, table 2) and measurements from the two platforms are within 27%. However, the DC-8 leg averaged values during the MBL run were only 40% of those measured on the P3-B (table 2) and similar to the MBL run during flight 1. Here the DC-8 scattering values were approximately equal to the P3-B sub-μm scattering coefficients, implying that virtually no coarse mode particles were making it into the DC-8 nephelometer during this leg. A layer of enhanced total scattering was encountered between 2 and 4 km altitude (~18.6 to 18.8 hrs) in very dry air (fig. 2e) during the descent profile (no impactor during profile). Here, the DC-8 and P3-B total scattering coefficients were very nearly equal. Figure 10b shows the P3-B OPC accumulation mode, coarse mode, and total aerosol surface areas ("dry") for this period. About 2/3 of the total aerosol surface area was due to coarse mode particles in both the 2-4 km layer as well as the MBL, suggesting a similar relationship of total to sub-μm scattering at both altitudes.

Aerosol Na and Ca mass concentrations for this flight are shown in figures 8a and b, respectively, and from the discussion in section 8.2.1, it appears that there is more dust relative to sea salt in the dry 2-4 km layer than in the MBL. Combining this information with the scattering data from comparison flights 1 and 2 (sections 5.2.2 and 5.2.1, respectively), it appears that the DC-8 scattering data was representative of total aerosol scattering in the "dry" FT, even with coarse mode dust present. In the "wet" MBL with sea salt present, the DC-8 scattering data appears to be representative of sub-μm scattering.

We believe that this difference in behavior is due primarily to two factors. The first is that despite attempts to keep the sample inlet isokinetic, the DC-8 SDI was super-isokinetic during MBL legs (but closer to isokinetic sampling aloft). This would artificially exclude most of the coarse aerosol in the MBL and also enhance turbulence within the inlet, increasing the loss of coarse aerosol to the inlet walls. This condition was probably exacerbated for "wet" sea salt compared to "dry" mineral dust since it is more likely to "stick" to the inlet walls after a collision.

Aerosol absorption coefficients measured on the DC-8 were within ~30% of the P3-B data when sampling in the MBL (flight 1). The agreement was within ~12% if one removed the large spike observed in the P3-B data on this flight. Aloft, DC-8 absorption was more variable and systematically higher than on the P3-B (by as much as a factor of 2). This leads to similar values from the two aircraft for single scatter albedo in the MBL, but unrealistically low values at higher altitudes. We therefore tentatively conclude that within the MBL, the DC-8 absorption data may have been representative, but in the FT, the DC-8 absorption measurements were systematically high due to unknown causes.

10.2 CN concentrations

For the majority of comparison flight legs, RCN concentrations agreed within 5-10% between all three aircraft. The exceptions to this were a high altitude P3-B/DC-8 leg during flight 5 and an individual P3-B/C-130 comparison during leg 2 of flight 3. The C-130 RCN counter during flight 3 experienced several failures (hence the lack of data for the remaining legs on this flight) and we attribute this discrepancy between RCN concentrations to poor RCN counter performance on the C-130 (for this flight). The RCN concentrations measured on the DC-8 and P3-B displayed different behaviors during the two high altitude inter-comparisons (both were at 5.2 km altitude). During flight 2 RCN concentrations were within 27% while during leg 1, flight 5, P3-B values were ~1/3 the DC-8 concentrations.

CN concentrations revealed that the C-130 data were systematically higher (from 30% to a factor of 2) than the P3-B measurements, although some legs did reveal reasonable agreement (table 2). However, the P3-B CN concentrations compared favorably (within 15%) to a second CN counter on the C-130 (operated by NCAR) for all comparison legs, suggesting the C-130 CN counter operated by the University of Hawaii group (utilized in fig. 4 and table 2) was over counting. After the comparison flights, this CN counter was tested and detector adjustments were made that resulted in better agreement between the two C-130 CN measurements.

DC-8/P3-B comparisons of CN concentrations exhibited agreement within ~25% for the majority of flight legs. Low level (MBL) runs showed agreement within 1% and 30% for flight 1 and leg 2, flight 5, respectively (table 2). After removing an outlier in the DC-8 data at approximately 19.1 hrs (fig. 4g), the agreement between the two platforms was ~15%. Results from high altitude comparisons of total CN were mixed. CN concentrations during comparison flight 2 agreed to within ~27% on the two aircraft while DC-8 CN measurements were ~50% higher than P3-B values for leg 1, flight 5 (table 2). These two legs were at the same altitude (5.2 km) and involved the same two aircraft, but the results showed a significant difference for both the RCN and CN concentrations.

This difference in high altitude DC-8/P3-B CN behavior is evident in DC-8/P3-B CN and RCN concentrations measured during the descent profile on flight 5 (fig. 11a). Near the surface, the CN concentrations were similar but differences increased below 700 mbar. Combined OPC and DMA number distributions as a function of diameter (x-axis) versus pressure (y-axis) are color-coded to concentration and plotted in figure 11b. At altitudes below 700 mbar, the size distributions revealed insignificant concentrations of the smallest particles. As pressure decreased, the distributions showed a shift to smaller sizes with large quantities of aerosol with diameters below 0.02 μm. Above 600 mbar altitude (where the differences between CN concentrations were greatest), the distributions showed that the number of particles with diameters below 0.015 μm (the nominal 50% cut size for the CN counters) was a significant fraction of the total number of aerosol. During flight 2 (also 5.2 km), DC-8/P3-B CN and RCN concentrations showed much better agreement (within 27%). Size distributions for this leg (not shown) revealed no significant concentrations of the smallest aerosols. The P3-B CN counter appears to have been undercounting in “clean air” aloft compared to the DC-8 when there were large concentrations of small aerosol. This undercounting is due to the differences between actual detection limits for the CN counters on the two aircraft. Note that minimum detection sizes can depend upon the saturator characteristics, the absolute

temperature and the nominal temperature difference between saturator and condensor that the CN counter attempts to control. The condensor and saturator temperatures were only recorded for the P3-B CN counters. Thus, if the P3-B CN and RCN counters had cut sizes just slightly larger than 0.015 μm (or if the DC-8 counters had cut sizes smaller than this), we would have expected large differences in reported CN concentrations. The DC-8 ΔT was set to 22 deg C (vs. 17 deg C for the P3-B CN counters) and its actual cut size should have been smaller than the 0.015 μm listed as nominal.

P3-B UCN concentrations were systematically lower than measurements on the other platforms when UCN concentrations were above several thousand #/cm^3 [Weber et al., 2003]. This was due to modifications of the instrument to obtain size distributions for particles with $0.003<=D_p<=0.01$ μm. These modifications effectively lowered the threshold for coincidence counting due to the increased sampling volume and made direct comparison difficult.

10.3 Aerosol Size Distributions and Integral Properties

There were not any DC-8 DMA data, so only DMA comparisons between the C-130 and P3-B were presented. During these comparisons, average DMA integral properties (table 2) displayed agreement within 25% for most legs. Several legs had greater discrepancies, but this was not surprising given the non-synchronous nature of the measurement (temperature cycling) and the high degree of variability of aerosol properties during these legs. DMA number distributions displayed agreement in sizing and concentration (both with each other and the corresponding overlap region of the OPC size distribution).

OPC (C-130/P3-B) and PCASP (DC-8) accumulation mode size distributions and integral properties also revealed agreement within 25% (frequently to within 10%), and tracked each other over large gradients and range of values. The average effective diameters derived from these measurements demonstrated that the instruments were sizing properly, relative to each other. Exceptions to this were for PCASP/OPC comparisons made at low altitudes where size distributions showed that the PCASP was underestimating the concentration of particles with diameters between 0.5 and 0.8 μm and in the peak of the distribution relative to the OPC. This may have been related to hygroscopic effects, but without a PCASP RH measurement this cannot be assessed.

Coarse mode measurements on the C-130 were consistently higher than those made on the P3-B. C-130 coarse mode surface areas were observed to be ~7% to ~30% higher than the P3-B data. Size distributions revealed that the differences between the two aircraft only became significant for particles with diameters greater than 2-3 μm. This is consistent with the results reported in the PELTI NSF Final Report [Huebert et al., 2000], leading us to conclude that the observed systematic differences in coarse mode OPC measurements made on the C-130 and P3-B were due to probable enhancements of larger particles by the LTI and losses in the SDI. The average effective diameters derived from the OPC coarse mode data were also shown to be in agreement with differences generally not more than 15% between the C-130 and P3-B.

Comparisons of FSSP coarse mode aerosol measurements between the three platforms were less clear. During the C-130/P3-B inter-comparisons, the FSSP integral coarse mode surface areas from the C-130 were systematically lower than those made on the P3-B for most flight legs by ~50-70%, but data from the two instruments did trend

together. The average effective diameter derived from the FSSP data showed that the C-130 FSSP was sizing at slightly larger diameters than the P3-B FSSP, but this discrepancy was not large. Two of the C-130/P3-B comparison legs showed the P3-B FSSP data to be less than the C-130 FSSP and also the two OPC's. This is not realistic and we take this as evidence that the P3-B FSSP was not functioning properly (for unknown reasons) during these two legs.

DC-8 FSSP data were not consistent with the P3-B FSSP or OPC measurements. DC-8 size distributions, integral properties, and average effective diameters all showed lower concentrations or values than P3-B data when sampling in "dry" air aloft that had a significant coarse dust component. DC-8 FSSP data was actually lower than the OPC data and this is unrealistic. DC-8 data when sampling in the "wet" MBL with a higher relative concentration of sea salt exhibited much higher concentrations and integral values than the P3-B measurements. Despite this, the average effective diameters derived from the two FSSP's were in good agreement when sampling under these conditions. As in the previous case, the P3-B FSSP data appears to be consistent with the OPC coarse mode measurements after allowing for hygroscopic growth. One would have to assume unrealistic growth factors for the DC-8 data to be consistent with the OPC. Currently, we do not understand this difference in DC-8 FSSP behavior (undercounting in "dry" dust aloft, overcounting in "wet" sea salt in the MBL) evident during the two DC-8/P3-B comparison flights and we are unable to suggest a method for consistent interpretation of DC-8 FSSP performance for the remainder of the TRACE-P field campaign.

10.4 Aerosol Chemistry

C-130/P3-B aerosol chemical concentrations were measured with identical PILS instruments (50% cut size of 1.3 μm) and the comparisons of chemical constituents between the two aircraft were reasonable for the majority of species. Comparisons of aerosol chemical concentrations between the DC-8 (bulk filter samples) and P3-B (PILS) showed that for the species normally associated with the coarse mode (Na, Ca, Mg, and Cl), the PILS data was systematically low as expected since the bulk filters collected particles for sizes less than ~7 μm while the PILS only effectively measured concentrations for aerosol diameters less than its cut size. However, the PILS data was also systematically lower than the DC-8 data for the species we normally associate with the accumulation mode (SO_4, NH_4, and NO_3) where we would not have expected significant differences between the two techniques. PILS sulfate concentrations agreed much better with the DC-8 MC/IC "fine" sulfate measurements (for which we do not know the cut size at present), suggesting that the differences for these species between PILS and the filter samples were due primarily to a significant fraction of these constituents being associated with the larger aerosol. Some of this coarse sulfate and nitrate may have been associated with sea salt or dust, the presence of both was suggested by the chemistry data.

To explore this possibility, we have combined the NH_4, SO_4, and NO_3 mass concentrations into a "combined" soluble mass (fig. 12). Using the STP corrected OPC volume (D_p < 1.3 μm, PILS cut size) and removing the refractory component (volume remaining after heating to 350 deg C), left the volatile fraction generally associated with sulfate, nitrate, and ammonium concentrations. Finally, we assumed a dry aerosol density of 1.8 g/cm^3 to estimate the resulting OPC volatile mass. Shown in figure 12a is

the P3-B and C-130 PILS “combined” soluble masses and the OPC volatile mass that reveal agreement between the three measurements within 15% for the entire comparison time period over an order of magnitude of values.

We also calculated the DC-8 “combined” soluble mass (bulk filters) and its “fine” component (MC/IC sulfate utilized in lieu of bulk sulfate). The DC-8 and PILS “combined” and OPC volatile masses are plotted again in figure 12b for comparison flight 5 and the “fine” data agreed to within 25% during the MBL leg (~19.0 to 19.5 hrs). The bulk filter data was significantly higher (approximately a factor of 2), suggesting that some of these soluble components were associated with the larger aerosol present (dust and sea salt). This is further illustrated in figure 12c, where the difference (Δmass) between the DC-8 total “combined” mass and the P3-B masses (OPC volatile and PILS “combined”) is plotted versus OPC coarse mode surface area. This figure has considerable scatter in the data points, but does suggest that Δmass increases with increasing coarse mode surface area. Figure 12d shows the same DC-8/P3-B derived masses for comparison flight 2. The DC-8 “fine” and P3-B PILS “combined” masses showed reasonable agreement for this flight, with the OPC “volatile” mass being intermediate between them. The DC-8 MC/IC “fine” sulfate cut size is believed to be higher than 1.3 μm and might be responsible for the DC-8 “fine” mass having been higher on this flight. The Δmass derived from the bulk DC-8 data and the P3-B PILS and OPC measurements are plotted against the OPC coarse mode surface area in figure 12e and show a much stronger relationship than figure 12c. Both figures are supportive of a significant fraction of the sulfate, nitrate, and ammonium being associated with the coarse aerosol.

10.5 Aerosol Optical Properties Revisited—A Regional Perspective:

The comparison of aerosol scattering and absorption revealed significant differences between the DC-8 and P3-B during individual comparison flights, depending on a variety of parameters including altitude, ambient RH, and aerosol composition. Two of the three flights were remote from the primary geographical focus of the TRACE-P experiment (the marine atmosphere close to the Asian coast). In the following, we will assess the performance of the DC-8 optical instruments for flights near the Asian continent.

The three panels of figure 13 plot scattering (fig. 13a), absorption (fig. 13b), and ω_0 (fig. 13c) versus altitude for the P3-B/DC-8 flights closest to Asia and most affected by Asian outflow (P3-B flights 8-19, DC-8 flights 6-17) and show "regional aerosol optical characteristics". In contrast to the MBL individual comparisons presented previously (comparison flights 1 and 5), the regional scattering profile (fig. 13a) reveals that the discrepancy between DC-8 and P3-B total scattering values was small, even at the lowest altitudes. This is probably due to the fact that near the continent, scattering values were dominated by the sub-μm component due to pollution aerosols and there was relatively less sea salt in the MBL near the continent than in the "clean" MBL in the central Pacific (flights 1 and 5), where super-μm and sub-μm scattering were nearly equal. From this plot, it appears that for flights near Asia, the DC-8 scattering values were generally consistent with those on the P3-B.

The "regional" absorption measurement (fig. 13b) indicates that the DC-8 absorption values were also consistent with those measured on the P3-B at the lowest

altitudes, but became systematically higher with increasing altitude. Similar behavior was seen in the plot of ω_0 (fig. 13c) where the P3-B measured ω_0 was nearly constant with altitude at ~0.9. DC-8 ω_0 values were near 0.9 at the surface and generally decreased to ~0.75 above 3 km (driven by the higher DC-8 absorption values). The results from this regional comparison of aerosol optical properties suggest that the DC-8 scattering values provide representative values near the continent at all altitudes, but that care should be utilized when using the DC-8 FT absorption coefficients (for calculating ω_0 and/or BC concentrations).

11 Conclusions:

Five inter-comparison flights were flown between the P3-B and the two other aircraft discussed in this paper (the DC-8 and C-130). These flights provided an opportunity to compare similar, simultaneous measurements made on the three platforms. Results from these comparisons of aerosol optical properties, concentrations, size distributions and integrals, and chemical constituents ranged from very good to poor and discrepancies in the data were discussed and explained when possible.

We conclude the following with confidence:

1. After allowing for the enhanced passing efficiency for the largest particles on the C-130 due to the LTI, aerosol optical properties (absorption and scattering) were consistent between the P3-B and C-130 aircraft.
2. The DC-8 scattering coefficients in the FT appear consistent with those on the P3-B. In the "clean" MBL remote from the continents, DC-8 scattering values underestimated total scattering and appears to be related to poor inlet performance in the "wet" MBL in the presence of higher relative concentrations of sea salt.
3. DC-8 absorption values appeared consistent with P3-B measurements in the MBL, but appeared unrealistically high in the FT. Resulting values of DC-8 ω_0 appeared too low for the upper altitudes.
4. RCN, total CN, and UCN concentrations showed poor instrument performance of the CN counters on several of the ACE-Asia/TRACE-P inter-comparison legs (due to problems that were corrected after the two comparison flights) but were generally consistent. The modifications to the P3-B UCN counter [Weber et al., 2003] resulted in generally lower counts compared to unmodified UCN counter. The difference between actual and nominal cut size for the P3-B counters resulted in some discrepancies that appeared most significant at altitude in "clean" air with large concentrations of small particles, but not for most of the experiment.
5. DMA and OPC/PCASP accumulation mode size distributions and integral properties agreed well with each other on the three platforms and accurately measured sub-μm aerosol size distributions.
6. OPC coarse mode measurements on the C-130 and P3-B were comparable and integral properties were within 10-20%, consistent with expected inlet performance.
7. The PILS instrument appears to have been accurately measuring soluble aerosol chemistry for particle sizes less than 1.3 μm. We expected small differences between the PILS (C-130/P3-B) measurements and bulk filter data (DC-8) for the aerosol normally associated with the accumulation mode (sulfate, nitrate, and ammonium), but the data presented (including OPC estimates of volatile

accumulation mode mass) suggested that this difference was at least partially due to the association of some of these species with sizes larger than the PILS cut size.

We also tentatively conclude the following:

8. Close to the Asian continent, plots of regional optical properties showed that the DC-8 (when compared to the P3-B measurements) was more accurately measuring total scattering than over remote regions. This was probably due to the higher contribution of sub-μm to total scattering and decreased relative concentrations of "wet" sea salt found near the continent.
9. P3-B and C-130 FSSP measurements appeared consistent with each other despite the larger discrepancies between the data for these two instruments, given the greater uncertainties inherent in the FSSP and poor counting statistics for the largest aerosol. DC-8 FSSP measurements appeared to overestimate concentrations in the "wet" MBL and underestimate concentrations in the "dry" FT. We do not understand this observed difference in DC-8 FSSP measurements at this time and cannot conclusively comment on how representative the DC-8 FSSP data was for the remainder of the TRACE-P experiment.

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FIGURES:

Figure 1: Flight tracks for the various aircraft during the inter-comparison flights. Also shown are the comparison legs. a) Flight tracks for the DC-8 and P3-B for flight 1. b) Flight tracks for the DC-8 and P3-B for flight 2. c) Flight tracks for the C-130 and P3-B for flight 3. d) Flight tracks for the C-130 and P3-B for flight 4. e) Flight tracks for the DC-8 and P3-B for flight 5.

Figure 2: a) Time series of altitude, ambient RH, and instrument RH (OPC's and nephelometers) for flight 1. b) Same as a), but for flight 2. c) Same as a), but for flight 3. d) Same as a), but for flight 4. e) Same as a), but for flight 5. Also shown in a) through e) are the locations of cloud penetrations that occurred during flights 1 and 5.

Figure 3: See figure 1 and table 1 for a complete listing of inter-comparison locations. Time series of aerosol optical properties (non-STP corrected) for selected comparison flights. a) Altitude and total and sub-μm scattering coefficients for flight 3 (ACE-Asia C-130/TRACE-P P3-B). b) Total and sub-μm absorption coefficients for the same flight. c) Total and sub-μm single scatter albedo for the same flight. d) Same as a), but for flight 2 (TRACE-P DC-8/P3-B). e) Same as b), but for flight 2. f) Same as c), but for flight 2. g) Same as a) (no sub-μm data for either platform), but for flight 1 (TRACE-P DC-8/P3-B). h) Same as b) (no sub-μm data for either platform), but for flight 1. A ship plume was encountered during this flight and is labeled. i) Same as c) (no sub-μm data for either platform), but for flight 1.

Figure 4: See figure 1 and table 1 for a complete listing of inter-comparison locations. Time series of refractory, total, and ultrafine CN concentrations and RCN ratios for selected comparison flights. Note that these concentrations have been STP corrected. a) Altitude and refractory and total CN for flight 4 (ACE-Asia C-130/TRACE-P P3-B). b) UCN concentrations for the same flight. c) RCN ratio for the same flight. d) Same as a),

but for flight 1 (TRACE-P DC-8/P3-B). A ship plume was encountered during this flight and is labeled. e) Same as b), but for flight 1. f) Same as c), but for flight 1. g) Same as a), but for flight 5 (TRACE-P DC-8/P3-B). h) Same as b), but for flight 5. i) Same as c), but for flight 5.

Figure 5: Leg-averaged combined DMA and OPC number distributions for comparison leg 4 during flight 3. The main panel is on a log-log scale in order to observe the number distribution out to the largest sizes. The inset shows the same distributions, but with a linear y-axis (concentration). Note that this data is not STP corrected.

Figure 6: See figure 1 and table 1 for a complete listing of inter-comparison locations. a) Time series of altitude and OPC accumulation mode integral surface areas for flight 3 (ACE-Asia C-130/TRACE-P P3-B). b) Time series of OPC and FSSP coarse mode integral surface areas for the same flight. c) Log-log plot of the leg-averaged OPC and FSSP surface area distributions for comparison leg 5 (log-log was chosen since the accumulation mode surface area dominates the coarse mode). d) Same as a), but for flight 2. e) Same as b), but for flight 2. f) Same as c), but for flight 2. These distributions are on a linear concentration scale since the accumulation and coarse mode distributions are of similar amplitudes. g) Same as a), but for flight 1. h) Same as b), but for flight 1. i) Same as c), but for flight 1 (concentration also on linear scale). Note that this data is not STP corrected.

Figure 7: Soluble aerosol chemical constituent concentrations measured with identical PILS instruments (50% cut size of 1.3 μm) during flight 3 (ACE-Asia C-130/TRACE-P P3-B). This data has been corrected to STP. Time series of a) altitude and Na, b) Ca, c) K, d) Mg, e) Cl, f) NH_4, g) SO_4, and h) NO_3 concentrations.

Figure 8: Soluble aerosol chemical constituent concentrations measured with bulk filters (DC-8) and PILS instrument (P3-B) during flight 5 (TRACE-P). This data has been corrected to STP. Time series of a) altitude and Na, b) Ca, c) K, d) Mg, e) Cl, f) NH_4, g) SO_4, and h) NO_3 concentrations. Also included in g) is the DC-8 MC/IC "fine" sulfate.

Figure 9: Same as figure 7, except for flight 2 (TRACE-P DC-8/P3-B). Also included in the figure are the ratios (black lines) of the DC-8 to the corresponding P3-B measurements.

Figure 10: a) Time series of altitude and total and sub-μm scattering coefficients for flight 5 (TRACE-P DC-8/P3-B). b) Time series of P3-B OPC total, accumulation mode, and coarse mode integral surface areas for the same flight. Note that none of these measurements are STP corrected.

Figure 11: a) Total and refractory CN concentrations (STP corrected) versus pressure for vertical descent profile during flight 5 (TRACE-P DC-8/P3-B). b) Profile of the combined DMA and OPC number distributions (STP corrected). The y-axis is pressure and the x-axis is aerosol diameter. The distributions are color-coded to aerosol concentration (at each diameter).

Figure 12: All data in this figure are STP corrected. a) Time series of PILS "combined" mass and OPC "volatile" mass (see text for description) for flight 3 (ACE-Asia C-130/TRACE-P P3-B). b) Same as a), but for flight 5 (TRACE-P DC-8/P3-B). The "combined" masses from the DC-8 utilizing the bulk filter data and the MC/IC "fine" sulfate are also shown. c) Scatter plot of the difference between the DC-8 bulk filter "combined" mass and the PILS "combined" mass and the OPC "volatile" mass (Δmass) versus the OPC coarse mode surface area for the same flight as in b). d) Same as b), but for flight 2 (TRACE-P DC-8/P3-B). e) Same as c), but for flight 2.

Figure 13: Vertical profiles of regional optical properties (no STP correction) measured on the DC-8 and P3-B for the intensive portion of the TRACE-P experiment near the Asian continent. a) Shows the vertical profile of altitude-averaged (0.25 km altitude bins) total scattering coefficients for DC-8/P3-B flights near the Asian continent below 6 km. b) Same as a), but for the altitude-averaged total absorption coefficients. c) Same as a), but for the altitude-averaged total single scatter albedo.

Table 1: Inter-comparison flights and horizontal leg information.

Inter-comparison Flt #	1	2	3	3	3	3	3	4	4	4	5	5
Aircraft Flt #	TRACE-P P3-B Flt 08 TRACE-P DC-8 Flt 06	TRACE-P P3-B Flt 16 TRACE-P DC-8 Flt 14	TRACE-P P3-B Flt 18 ACE-Asia C-130 Flt 01					TRACE-P P3-B Flt 19 ACE-Asia C-130 Flt 02			TRACE-P P3-B Flt 23 TRACE-P DC-8 Flt 20	
# of Horizontal Legs	1	1	5					3			2	
Date	03/04/01	03/23/01	03/30/01					04/02/01			04/09/01	
Location	NW of Guam 14 °N Latitude 142 °E Longitude	SE of Japan 33 °N Latitude 138 °E Longitude	W & SW of Japan 34 °N Latitude 130 °E Longitude					W of Japan 38 °N Latitude 135 °E Longitude			NE of Hawaii 25 °N Latitude 148 °W Longitude	
Leg #	1	1	1	2	3	4	5	1	2	3	1	2
Leg Times (GMT, hrs)	01:10-01:30	24:01-24:30	00:54-01:33	01:41-02:01	02:09-02:27	02:32-02:38	03:00-03:24	02:12-03:10	03:12-03:40	04:30-04:51	06:03-06:25	07:00-07:19
Leg Altitudes (km)	0.2	5.2	0.2	2.5	0.9	0.1	0.9	0.2	0.6	1.7	5.2	0.2
Average Leg Ambient RH (%)	77	24	53	8	64	44	70	70	82	15	12	63
Comments	"clean" MBL	pollution and dust, FT	pollution, dust, and sea salt, MBL and lower FT					pollution, dust, and sea salt, MBL and lower FT			"clean" FT and "semi-polluted" MBL	

Table 2: Inter-comparison legs, means and variances of aerosol microphysical and optical properties. Means of the following parameters were taken over time periods where there were measurements on both platforms. Variances are reported as standard deviations for the same time periods. P3-B values (marked by P) of means and variances are given first, followed by the same for the second platform (D—DC-8 and C—C-130). The third entries are the ratios of the means and variances (C-130/DC-8 data divided by P3-B data). The number of data points utilized in calculating the means and variances are given in brackets in the fourth entry. For the majority of the physical measurements (CN concentrations, scattering and absorption coefficients, and FSSP measurements), the leg averages were calculated only when there were simultaneous measurements on both platforms resulting in the same number of data. OPC and DMA data was included regardless of whether or not there were coincidental measurements since these data were neither simultaneous nor continuous. For these entries, the P3-B number of data points is reported first. Inter-comparison legs where data was not available from one of the platforms for the entire leg are marked by "No data" and corresponding "N/A" for the platform where data was available. Legs with the ratio of the means within 25% are considered "reasonable" and underlined while legs with ratios outside of 35% or with systematic differences are marked with asterisks and will be addressed in the discussion section.

Flight #	1	2	3	3	3	3	3
Inter-comparison Leg	1 P3-B/DC-8 03/04/01	1 P3-B/DC-8 03/24/01	1 P3-B/C-130 03/30/01	2 P3-B/C-130 03/30/01	3 P3-B/C-130 03/30/01	4 P3-B/C-130 03/30/01	5 P3-B/C-130 03/30/01

Heated CN conc. (#/cm^3)	P 165 (41) D 167 (73) 1.01 (1.76) [20]	P 469 (180) D 595 (225) 1.27 (1.25) [28]	N/A No Data	P 378 (111) C 252 (54) * 0.67 (0.48) [19]	N/A No Data	N/A No Data	N/A No Data
Unheated CN conc. (#/cm^3)	P 222 (48) D 259 (74) 1.17 (1.53) [20]	P 772 (253) D 972 (324) 1.26 (1.28) [28]	P 1830 (341) C 1909 (385) 1.04 (1.13) [39]	P 599 (267) C 691 (556) 1.15 (2.08) [20]	P 3472 (582) C 4651 (782) * 1.34 (1.34) [18]	P 2518 (187) C 4044 (306) * 1.61 (1.64) [6]	P 2053 (145) C 2717 (115) * 1.32 (0.79) [24]
RCN ratio	P 0.74 (0.02) D 0.61 (0.11) 0.82 (4.71) [20]	P 0.60 (0.05) D 0.60 (0.03) 1.01 (0.71) [28]	N/A No Data	P 0.68 (0.11) C 0.48 (0.11) * 0.71 (1.07) [19]	N/A No Data	N/A No Data	N/A No Data
Total Scattering Coeff. @ 550 nm (Mm^{-1})	P 30.98 (2.29) D 7.19 (1.04) * 0.23 (0.46) [19]	P 11.95 (4.30) D 13.18 (3.79) 1.10 (0.88) [23]	P 49.28 (9.93) C 54.92 (11.67) * 1.11 (1.18) [13]	P 14.52 (2.68) C 26.61 (14.61) * 1.83 (5.45) [10]	P 78.70 (9.82) C 88.99 (10.02) * 1.13 (1.02) [8]	P 61.99 (3.97) C 71.57 (3.12) * 1.15 (0.79) [6]	P 49.02 (3.60) C 57.65 (1.97) * 1.18 (0.55) [7]
Sub-µm Scattering Coeff. @ 550 nm (Mm^{-1})	No Data No Data	N/A No Data	P 39.11 (8.75) C 38.73 (8.72) 0.99 (1.00) [13]	P 12.48 (1.49) C 9.05 (1.48) 0.72 (0.99) [8]	P 67.91 (6.69) C 65.73 (6.60) 0.97 (0.99) [8]	No Data N/A	P 43.20 (3.58) C 39.39 (2.57) 0.91 (0.72) [11]
Total Absorption Coeff. @ 565 nm (550 nm for C-130) (Mm^{-1})	P 0.52 (0.00) D 0.35 (0.00) * 0.69 (0.00) [1]	P 0.79 (0.24) D 1.71 (1.07) * 2.16 (4.39) [15]	P 6.60 (0.91) C 7.51 (1.13) * 1.14 (1.25) [7]	P 1.01 (0.00) C 1.79 (0.00) * 1.77 (0.00) [1]	N/A No Data	N/A No Data	N/A No Data
Total Co-Albedo	P 0.02 (0.00) D 0.06 (0.00) * 3.38 (0.00) [1]	P 0.06 (0.01) D 0.11 (0.05) * 1.84 (7.07) [15]	P 0.11 (0.01) C 0.12 (0.01) 1.01 (1.20) [6]	P 0.06 (0.00) C 0.06 (0.00) 0.96 (0.00) [1]	N/A No Data	N/A No Data	N/A No Data
DMA Integral Number (#/cm^3)	N/A No Data	N/A No Data	P 549 (33.00) C 1041 (30.00) 1.90 (0.91) [P 5,C 7]	P 117 (89.05) C 92 (8.32) 0.78 (0.09) [P 3,C 3]	P 935 (23.04) C 907 (131.50) 0.97 (5.71) [P 2,C 3]	P 671 (8.86) C 633 (169.23) 0.94 (19.10) [P 2,C 2]	P 571 (48.43) C 500 (37.51) 0.88 (0.78) [P 5,C 4]
DMA Integral Surface Area (µm^2/cm^3)	N/A No Data	N/A No Data	P 5.98 (2.95) C 8.16 (3.93) 1.37 (1.33) [P 5,C 7]	P 1.52 (0.97) C 1.52 (0.05) 1.00 (0.05) [P 3,C 3]	P 13.72 (0.56) C 14.17 (1.77) 1.03 (3.16) [P 2,C 3]	P 9.84 (0.30) C 10.05 (3.14) 1.02 (10.42) [P 2,C 2]	P 7.76 (0.43) C 7.71 (0.59) 1.00 (1.36) [P 5,C 4]
DMA Integral Volume (µm^3/cm^3)	N/A No Data	N/A No Data	P 0.08 (0.04) C 0.11 (0.05) 1.38 (1.33) [P 5,C 7]	P 0.02 (0.01) C 0.02 (0.00) 1.07 (0.08) [P 3,C 3]	P 0.18 (0.01) C 0.18 (0.02) 1.05 (2.57) [P 2,C 3]	P 0.13 (0.00) C 0.13 (0.04) 1.04 (9.32) [P 2,C 2]	P 0.10 (0.01) C 0.10 (0.01) 1.01 (1.13) [P 5,C 4]
OPC (PCASP on DC-8) Accumulation Mode Integral Number (#/cm^3)	P 105 (12.00) D 70 (5.69) 0.67 (0.47) [P 7,D 20]	P 115 (38.42) D 148 (38.90) 1.28 (1.01) [P 10,D 27]	P 1282 (228.06) C 1264 (271.35) 0.99 (1.19) [P 10,C 26]	P 196 (46.44) C 216 (55.03) 1.10 (1.19) [P 7,C 13]	P 1817 (163.62) C 1799 (298.99) 0.99 (1.83) [P 6,C 12]	P 1615 (0.00) C 1423 (415.24) 0.88 (NA) [P 2,C 4]	P 1091 (119.82) C 1070 (120.45) 0.98 (1.01) [P 8,C 23]
OPC (PCASP on DC-8) Accumulation Mode Integral Surface Area (µm^2/cm^3)	P 15.46 (1.73) D 8.77 (0.81) 0.57 (0.47) [P 7,D 20]	P 14.42 (4.48) D 11.05 (2.86) 0.77 (0.64) [P 10,D 27]	P 154.92 (27.05) C 166.55 (36.48) 1.08 (1.35) [P 10,C 26]	P 26.02 (5.90) C 30.56 (7.79) 1.17 (1.32) [P 7,C 13]	P 227.29 (22.83) C 246.85 (43.28) 1.09 (1.90) [P 6,C 12]	P 193.29 (0.00) C 178.38 (52.22) 0.92 (NA) [P 2,C 4]	P 133.71 (14.92) C 134.86 (13.67) 1.01 (0.92) [P 8,C 23]
OPC (PCASP on DC-8) Accumulation Mode Integral Volume (µm^3/cm^3)	P 0.83 (0.10) D 0.45 (0.06) 0.55 (0.57) [P 7,D 20]	P 0.69 (0.21) D 0.54 (0.14) 0.79 (0.67) [P 10,D 27]	P 6.37 (1.12) C 7.19 (1.64) 1.13 (1.47) [P 10,C 26]	P 1.13 (0.26) C 1.32 (0.35) 1.16 (1.34) [P 7,C 13]	P 9.55 (1.01) C 11.09 (2.05) 1.16 (2.03) [P 6,C 12]	P 8.00 (0.00) C 7.58 (2.37) 0.95 (NA) [P 2,C 4]	P 5.59 (0.63) C 5.73 (0.59) 1.02 (0.93) [P 8,C 23]
OPC Coarse Mode Integral Number (#/cm^3)	N/A No Data	N/A No Data	P 1.56 (0.28) C 1.18 (0.48) 0.76 (1.68) [P 10,C 26]	P 1.08 (0.16) C 2.07 (2.40) 1.91 (15.50) [P 7,C 13]	P 2.24 (0.13) C 1.42 (0.52) 0.63 (3.88) [P 6,C 12]	P 2.14 (0.27) C 1.33 (0.58) 0.62 (2.13) [P 2,C 4]	P 2.34 (0.16) C 1.80 (1.19) 0.77 (7.39) [P 8,C 23]
OPC Coarse Mode Integral Surface Area (µm^2/cm^3)	N/A No Data	N/A No Data	P 9.43 (2.03) C 12.52 (4.41) 1.33 (2.18) [P 10,C 26]	P 13.97 (4.42) C 14.96 (8.31) 1.07 (1.88) [P 7,C 13]	P 13.74 (1.39) C 15.40 (2.67) 1.12 (1.93) [P 6,C 12]	P 15.10 (2.19) C 20.12 (10.41) 1.33 (4.76) [P 2,C 4]	P 16.01 (2.85) C 15.05 (3.39) 0.94 (1.19) [P 8,C 23]
OPC Coarse	N/A	N/A	P 4.45 (1.87)	P 8.79 (3.89)	P 7.03 (1.92)	P 8.97 (2.74)	P 8.88 (4.70)

Mode Integral Volume ($\mu m^3/cm^3$)	No Data	No Data	C 6.61 (3.51) 1.47 (1.88) [P 10,C 26]	C 9.79 (6.76) 1.11 (1.74) [P 7,C 13]	C 8.31 (3.36) 1.18 (1.75) [P 6,C 12]	C 19.92 (18.67) 2.22 (6.82) [P 2,C 4]	C 7.49 (4.02) 0.84 (0.86) [P 8,C 23]
FSSP Coarse Mode Integral Number ($\#/cm^3$)	P 1.39 (0.17) D 3.44 (1.64) 2.46 (9.42) [20]	P 1.06 (0.40) D 0.43 (0.25) 0.41 (0.62) [27]	P 0.39 (0.14) C 0.73 (0.23) 1.85 (1.56) [39]	P 0.30 (0.09) C 0.46 (0.16) 1.50 (1.69) [20]	P 1.06 (0.10) C 1.07 (0.11) 1.01 (1.20) [18]	P 1.06 (0.10) C 1.07 (0.07) 1.01 (0.68) [6]	P 1.64 (0.34) C 1.64 (0.46) 1.00 (1.35) [24]
FSSP Coarse Mode Integral Surface Area ($\mu m^2/cm^3$)	P 50.35 (7.92) D 97.99 (47.45) 1.95 (5.99) [20]	P 54.26 (25.62) D 6.08 (4.01) 0.11 (0.16) [27]	P 12.97 (17.67) C 23.51 (12.76) 1.81 (0.72) [39]	P 3.56 (0.78) C 10.99 (4.02) 3.09 (5.15) [20]	P 44.83 (6.04) C 29.97 (3.49) 0.67 (0.58) [18]	P 33.93 (7.63) C 31.26 (1.52) 0.92 (0.20) [6]	P 78.34 (26.02) C 56.88 (23.77) 0.73 (0.91) [24]
FSSP Coarse Mode Integral Volume ($\mu m^3/cm^3$)	P 44.67 (10.02) D 83.02 (41.60) 1.86 (4.15) [20]	P 67.33 (36.14) D 4.34 (3.89) 0.06 (0.11) [27]	P 16.89 (38.03) C 28.09 (29.33) 1.66 (0.77) [39]	P 0.32 (0.07) C 8.08 (3.37) 25.39 (45.44) [20]	P 51.61 (10.26) C 31.12 (6.54) 0.60 (0.64) [18]	P 33.74 (13.42) C 27.90 (2.08) 0.83 (0.16) [6]	P 98.94 (43.86) C 66.09 (36.56) 0.67 (0.83) [24]

Table 2 (cont.):

Flight #	4	4	4	5	5
Inter-comparison Leg	1 P3-B/C-130 04/02/01	2 P3-B/C-130 04/02/01	3 P3-B/C-130 04/02/01	1 P3-B/DC-8 04/09/01	2 P3-B/DC-8 04/09/01
Heated CN conc. ($\#/cm^3$)	P 3537 (407) C 3851 (385) 1.09 (0.95) [58]	P 3444 (386) C 3574 (365) 1.04 (0.95) [30]	P 348 (61) C 332 (63) 0.95 (1.03) [21]	P 49 (7) D 163 (8) 3.31 (1.06) [17]	P 187 (24) D 196 (198) 1.05 (8.14) [19]
Unheated CN conc. ($\#/cm^3$)	P 4821 (445) C 7127 (801) 1.48 (1.80) [58]	P 5256 (1198) C 7603 (2273) 1.45 (1.90) [30]	P 598 (47) C 636 (51) 1.06 (1.09) [21]	P 1763 (52) D 2703 (126) 1.53 (2.42) [17]	P 271 (32) D 354 (268) 1.31 (8.41) [19]
RCN ratio	P 0.73 (0.02) C 0.54 (0.02) 0.74 (0.68) [58]	P 0.67 (0.09) C 0.49 (0.09) 0.74 (1.01) [30]	P 0.58 (0.08) C 0.52 (0.09) 0.90 (1.14) [21]	P 0.03 (0.00) D 0.06 (0.00) 2.16 (0.73) [17]	P 0.69 (0.01) D 0.52 (0.02) 0.75 (1.18) [19]
Total Scattering Coeff. @ 550 nm (Mm^{-1})	P 104.47 (30.44) C 126.89 (30.80) 1.21 (1.01) [28]	P 108.29 (19.30) C 133.33 (21.74) 1.23 (1.13) [15]	P 6.00 (1.06) C 7.43 (1.18) 1.24 (1.12) [10]	P 0.61 (0.06) D 0.78 (0.23) 1.27 (3.84) [17]	P 24.52 (3.65) D 10.11 (0.81) 0.41 (0.22) [14]
Sub-μm Scattering Coeff. @ 550 nm (Mm^{-1})	P 93.32 (26.80) C 95.39 (30.01) 1.01 (1.12) 1.02 [21]	P 77.67 (12.50) C 75.24 (12.67) 0.97 (1.01) [15]	P 6.07 (1.18) C 4.75 (0.83) 0.78 (0.71) [5]	No Data No Data	N/A No Data
Total Absorption Coeff. @ 565 nm (550 nm for C-130) (Mm^{-1})	P 10.96 (4.05) C 12.88 (3.44) 1.18 (0.85) [20]	P 11.10 (1.84) C 13.62 (2.30) 1.23 (1.26) [9]	P 0.75 (0.45) C 1.08 (1.77) 1.45 (3.94) [5]	P 0.10 (0.04) D 0.22 (0.16) 2.22 (3.61) [10]	P 0.80 (0.29) D 1.11 (0.31) 1.39 (1.08) [10]
Total Co-Albedo	P 0.10 (0.02) C 0.10 (0.00) 0.99 (0.26) [20]	P 0.09 (0.01) C 0.09 (0.00) 0.98 (0.19) [9]	P 0.09 (0.07) C 0.07 (0.23) 0.77 (3.52) [5]	P 0.13 (0.07) D 0.21 (0.11) 1.64 (1.63) [10]	P 0.03 (0.01) D 0.10 (0.03) 3.03 (2.20) [10]
DMA Integral	P 1464 (599.46)	P 981 (1086.57)	P 112 (62.77)	N/A	N/A

Number (#/cm^3)	C 1041 (573.22) 0.71 (0.96) [P 7,C 9]	C 861 (753.87) 0.88 (0.69) [P 5,C 5]	C 125 (105.20) 1.11 (1.68) [P 3,C 3]	No Data	No Data
DMA Integral Surface Area (μm^2/cm^3)	P 18.21 (8.86) C 16.55 (8.53) 0.91 (0.96) [P 7,C 9]	P 8.81 (9.15) C 13.30 (11.33) 1.51 (1.24) [P 5,C 5]	P 1.06 (0.83) C 1.74 (1.41) 1.65 (1.71) [P 3,C 3]	N/A No Data	N/A No Data
DMA Integral Volume (μm^3/cm^3)	P 0.23 (0.12) C 0.22 (0.11) 0.94 (0.94) [P 7,C 9]	P 0.08 (0.08) C 0.17 (0.15) 2.17 (1.93) [P 5,C 5]	P 0.01 (0.01) C 0.02 (0.02) 1.76 (1.74) [P 3,C 3]	N/A No Data	N/A No Data
OPC (PCASP on DC-8) Accumulation Mode Integral Number (#/cm^3)	N/A No Data	N/A No Data	N/A No Data	P 10 (1.36) D 25 (1.99) 2.44 (1.46) [P 6,D 22]	P 172 (20.14) D 122 (22.06) 0.71 (1.10) [P 6,D 19]
OPC (PCASP on DC-8) Accumulation Mode Integral Surface Area (μm^2/cm^3)	N/A No Data	N/A No Data	N/A No Data	P 1.01 (0.18) D 1.04 (0.13) 1.03 (0.70) [P 6,D 22]	P 26.37 (2.80) D 17.14 (4.21) 0.65 (1.51) [P 6,D 19]
OPC (PCASP on DC-8) Accumulation Mode Integral Volume (μm^3/cm^3)	N/A No Data	N/A No Data	N/A No Data	P 0.04 (0.01) D 0.04 (0.01) 0.91 (0.69) [P 6,D 22]	P 1.32 (0.14) D 0.88 (0.27) 0.67 (1.97) [P 6,D 19]
OPC Coarse Mode Integral Number (#/cm^3)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	N/A No Data
OPC Coarse Mode Integral Surface Area (μm^2/cm^3)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	N/A No Data
OPC Coarse Mode Integral Volume (μm^3/cm^3)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	N/A No Data
FSSP Coarse Mode Integral Number (#/cm^3)	P 3.67 (1.18) C 3.00 (1.06) 0.82 (0.90) [58]	P 4.55 (1.55) C 2.98 (0.97) 0.65 (0.63) [30]	P 0.10 (0.03) C 0.06 (0.02) 0.59 (0.52) [30]	N/A No Data	N/A No Data
FSSP Coarse Mode Integral Surface Area (μm^2/cm^3)	P 117.62 (46.22) C 77.20 (31.35) 0.66 (0.68) [58]	P 181.58 (77.34) C 87.02 (36.12) 0.48 (0.47) [30]	P 2.50 (1.19) C 1.33 (0.75) 0.53 (0.64) [30]	N/A No Data	N/A No Data
FSSP Coarse Mode Integral Volume (μm^3/cm^3)	P 114.37 (55.16) C 77.08 (34.61) 0.67 (0.63) [58]	P 202.53 (103.42) C 93.09 (44.80) 0.46 (0.43) [30]	P 1.81 (1.65) C 1.00 (0.93) 0.55 (0.56) [30]	N/A No Data	N/A No Data

Table 3: Inter-comparison legs, means and variances of aerosol chemical constituents. Means of the following parameters were taken over time periods where there were measurements on both platforms. Variances are reported as standard deviations for the same time periods. P3-B values (marked by P) of means and variances are given first, followed by the same for the second platform (D—DC-8 and C—C-130). The third entries are the ratios of the means and variances (C-130/DC-8 data divided by P3-B data). The number of data points utilized in calculating the means and variances are given in brackets in the fourth entry with the P3-B number of data points being reported first. Inter-comparison legs where data was not available from one of the platforms for the entire leg are marked by "No data" and corresponding "N/A" for the platform where data was available. Legs with the ratio of the means within 25% are considered "reasonable" and underlined while legs with ratios outside of 35% are marked with asterisks and will be addressed in the discussion section.

Flight #	1	2	3	3	3	3	3
Inter-comparison Leg	1 P3-B/DC-8 03/04/01	1 P3-B/DC-8 03/24/01	1 P3-B/C-130 03/30/01	2 P3-B/C-130 03/30/01	3 P3-B/C-130 03/30/01	4 P3-B/C-130 03/30/01	5 P3-B/C-130 03/30/01
Na ($\mu g/stdm^3$)	P 0.70 (0.03) D 2.84 (0.08) 4.08 (3.11) [P 18,D 20]	P 0.09 (0.04) D 0.26 (0.11) 2.85 (2.85) [P 26,D 26]	P 0.14 (0.07) C 0.04 (0.02) 0.30 (0.33) [P 39,C 26]	P 0.07 (0.05) C 0.03 (0.00) 0.45 (0.07) [P 26,C 10]	P 0.18 (0.02) C 0.05 (0.03) 0.28 (1.12) [P 18,C 18]	P 0.29 (0.01) C 0.08 (0.01) 0.26 (1.74) [P 6,C 6]	P 0.43 (0.10) C 0.16 (0.07) 0.38 (0.68) [P 24,C 24]
Ca ($\mu g/stdm^3$)	No Data N/A	P 0.36 (0.13) D 1.44 (0.45) 3.99 (3.34) [P 26,D 26]	P 0.02 (N/A) C 0.06 (N/A) 2.61 (N/A) [P 4,C 6]	P 0.02 (N/A) C 0.08 (0.05) 4.10 (N/A) [P 2,C 27]	P 0.05 (0.01) C 0.05 (0.03) 1.02 (2.10) [P 15,C 10]	P 0.11 (N/A) C 0.04 (N/A) 0.40 (N/A) [P 2,C 4]	N/A No Data
Mg ($\mu g/stdm^3$)	P 0.09 (0.01) D 0.29 (0.01) 3.19 (1.10) [P 18,D 20]	P 0.03 (0.01) D 0.23 (0.06) 6.75 (4.21) [P 18,D 26]	P 0.03 (0.01) C 0.04 (0.02) 1.69 (1.64) [P 12,C 27]	P 0.02 (0.01) C 0.04 (0.01) 1.48 (1.01) [P 8,C 19]	N/A No Data	P 0.04 (0.00) C 0.04 (0.00) 1.09 (0.00) [P 6,C 2]	P 0.07 (0.02) C 0.03 (0.01) 0.42 (0.44) [P 24,C 12]

Cl ($\mu g/stdm^3$)	P 2.38 (0.08) D 2.50 (0.12) 1.05 (1.40) [P 18,D 20]	P 0.05 (0.03) D 0.19 (0.08) 3.90 (3.13) [P 24,D 26]	P 0.15 (0.09) C 0.14 (0.06) 0.91 (0.61) [P 39,C 39]	P 0.10 (0.06) C 0.07 (0.05) 0.69 (0.75) [P 12,C 31]	P 0.25 (0.02) C 0.20 (0.02) 0.80 (1.02) [P 18,C 18]	P 0.35 (0.01) C 0.29 (0.01) 0.83 (0.84) [P 6,C 6]	P 0.61 (0.14) C 0.48 (0.10) 0.79 (0.68) [P 24,C 24]
NH_4 ($\mu g/stdm^3$)	P 0.28 (0.02) D 0.14 (0.00) 0.50 (0.07) [P 18,D 20]	P 0.05 (N/A) D 0.24 (0.07) 4.88 (N/A) [P 4,D 26]	P 1.27 (0.34) C 1.72 (0.29) 1.36 (0.85) [P 39,C 35]	P 0.69 (0.77) C 0.87 (0.84) 1.26 (1.08) [P 30,C 31]	P 2.43 (0.31) C 2.73 (0.36) 1.12 (1.18) [P 18,C 18]	P 1.80 (0.12) C 1.97 (0.03) 1.10 (0.25) [P 6,C 6]	P 1.45 (0.20) C 1.70 (0.12) 1.17 (0.61) [P 24,C 24]
NO_3 ($\mu g/stdm^3$)	P 0.11 (0.02) D 0.03 (0.02) 0.26 (0.83) [P 18,D 20]	P 0.18 (0.04) D 0.40 (0.09) 2.15 (2.05) [P 26,D 26]	P 0.37 (0.20) C 0.44 (0.27) 1.19 (1.35) [P 39,C 35]	P 0.45 (0.46) C 0.95 (0.66) 2.12 (1.44) [P 30,C 24]	P 1.98 (0.73) C 2.36 (0.82) 1.19 (1.13) [P 18,C 18]	P 0.84 (0.09) C 0.94 (0.05) 1.12 (0.58) [P 6,C 6]	P 0.68 (0.09) C 0.76 (0.10) 1.12 (1.14) [P 24,C 24]
SO_4 ($\mu g/stdm^3$)	P 0.49 (0.03) D 0.50 (0.01) 1.01 (0.34) [P 18,D 20]	P 0.56 (0.21) D 1.28 (0.34) 2.80 (2.89) [P 26,D 26]	P 4.44 (0.77) C 5.80 (0.87) 1.31 (1.13) [P 39,C 39]	P 1.85 (1.94) C 2.86 (2.43) 1.55 (1.25) [P 30,C 31]	P 6.19 (0.45) C 7.67 (0.57) 1.24 (1.26) [P 18,C 18]	P 5.23 (0.29) C 6.44 (0.18) 1.23 (0.64) [P 6,C 6]	P 4.72 (0.63) C 5.93 (0.33) 1.26 (0.52) [P 24,C 24]
"fine" SO_4 ($\mu g/stdm^3$)	P 0.49 (0.03) D 0.22 (0.09) 0.44 (2.93) [P 18,D 20]	P 0.56 (0.21) D 1.28 (0.34) 2.31 (1.60) [P 26,D 27]	N/A No Data	N/A No Data	N/A No Data	N/A No Data	N/A No Data

Table 3 (cont.):

Flight #	4	4	4	5	5
Inter-comparison Leg	1 P3-B/C-130 04/02/01	2 P3-B/C-130 04/02/01	3 P3-B/C-130 04/02/01	1 P3-B/DC-8 04/09/01	2 P3-B/DC-8 04/09/01
Na ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	P 0.21 (0.04) D 4.35 (0.69) 20.58 (18.71) [P 19,D 19]
Ca ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	P 0.06 (0.01) D 0.28 (0.07) 5.02 (10.53) [P 7,D 16]
Mg ($\mu g/stdm^3$)	N/A No Data	N/A No Data	No Data No Data	N/A No Data	P 0.03 (0.01) D 0.50 (0.09) 15.75 (7.99) [P 7,D 19]
Cl ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	P 0.31 (0.08) D 7.56 (1.21) 24.54 (14.68) [P 19,D 19]
NH_4 ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	P 0.05 (N/A) D 0.02 (0.00) 0.46 (N/A) [P 3,D 22]	P 0.40 (0.09) D 0.70 (0.14) 1.77 (1.56) [P 19,D 19]
NO_3 ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	No Data No Data	P 0.05 (0.01) D 0.29 (0.05) 6.29 (6.37) [P 19,D 19]
SO_4 ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	N/A No Data	P 1.05 (0.23) D 2.12 (0.33) 2.02 (1.42) [P 19,D 19]
"fine" SO_4 ($\mu g/stdm^3$)	N/A No Data	N/A No Data	N/A No Data	P 0.10 (0.02) D 0.25 (0.19)	P 1.05 (0.23) D 0.81 (0.17)

				2.56 (10.85) [P 17,D 22]	0.77 (0.75) [P 19,D 19]